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Journal of Computer and Communications, 2024, 12, 107-145
https://www.scirp.org/journal/jcc
ISSN Online: 2327-5227
ISSN Print: 2327-5219

SAGeLogE: A Decision Support System for Students' Accommodation Management

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How to cite this paper: Rasoanaivo, R.G. and Zaraté, P. (2024) SAGeLogE: A Decision Support System for Students' Accommodation Management. *Journal of Computer and Communications*, **12**, 107-145.
https://doi.org/10.4236/jcc.2024.123008

Received: February 6, 2024
Accepted: March 23, 2024
Published: March 26, 2024

Abstract

SAGeLogE is the acronym of "**S**ystème d'**A**ide à la **Ge**stion de **Log**ements **É**tudiants" which means student accommodation management support system. It's a multi-criteria decision support system designed to manage accommodation allocation for university students. Within SAGeLogE we developed the "Minimum of Ranks" (MIRA) aggregation method. MIRA method involves the application of multi-criteria decision-making methods (MCDM) to initially obtain different ranking. Thus, we chose the Weighted Sum Method (WSM), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Combined Compromise Solution (CoCoSo) methods to be implemented in SAGeLogE. To prioritize the weights of criteria, the Anality Hierarchy Process (AHP) method was used. The interest of using the MIRA method was to obtain a compromised ranking coming from these three multi-criteria decision-making methods (WSM, TOPSIS, CoCoSo). So, we know that the accommodation to be allocated to students is always lower than the number of accommodation requests received by the organization. Thus, SAGeLogE proposed a technique that makes it easier to select students ranked by the multi-criteria decision-making and MIRA methods according to a method of calculation of quota of available accommodations within university residences. Finally, university accommodation managers had a wide choice of student ranking according to the methods implemented in SAGeLogE. The SAGeLogE experiment was carried out on the site of Toamasina University in Madagascar for an academic year with 2026 student accommodation applications received. The experimentation showed the ability of SAGeLogE to achieve the result.

Keywords

MIRA Method, MCDM, Accommodation Quota, SAGeLogE

1. Introduction

Student accommodation is one of the subjects that interests stakeholders in the field of higher education because it will be impossible to separate it from university life [1]. Each academic year, several students apply for accommodation from the organizations responsible for managing it to try their luck at living in a university residence. Unfortunately, the accommodation rate for students is low following the growth in their numbers enrolled in universities. In Australia, only 3.78% of students are accommodated in university residence in 2016 [2]. In France, 12% of students were admitted living in university residences in 2020 [3]. In Madagascar, notably in the Université de Toamasina, 15% of students resided on Barikadimy's campus in 2022 [4]. In the United Kingdom, 27% of students benefited from accommodation in 2022 [5].

Universities commonly choose accommodation allocation criteria and assign values to each of these criteria to rank students according to the sum of points they obtain. Thus, accommodation will be allocated to students who have had the maximum points [6]. There are several accommodation allocation criteria used by universities such as the physical capacity of the student, the composition of their family, the kilometer distance of the student's place of residence from the university, the level of study, age, teaching registration, admission to the exam, etc. [7] [8] [9] [10].

Given the multiplicity and contradiction between chosen criteria by universities, the application of an appropriate method is essential instead of simply adding up the grades obtained by students. The simple method used by universities favours students who have the maximum points on all criteria. It is an optimization technique, while optimization is generally used for single-criteria problem type.

Faced with multiple and contradictory criteria, multi-criteria decision-making methods were created to resolve this type of problem. Consequently, the student accommodation allocation problem can be solved by multi-criteria decision methodologies.

This is the reason why we chose to use the "Minimum of Ranks" (MIRA) method to deal with this student accommodation allocation problem. MIRA is a recent ranking aggregating method. It uses at least two multi-criteria decision-making methods to rank the alternatives from each of the methods. Then, the rank correlation of each multicriteria decision-making method will be calculated in relation to them. If the multi-criteria methods have the same direction of correlation, MIRA will then be applied by aggregating the ranks obtained by the multi-criteria methods. The purpose of applying the MIRA method is to obtain a single ranking resulting from multi-criteria decision-making methods. It will simplify the Decision Makers decision if they have only one ranking instead of several ranking coming different MCDM. The ranking obtained by the MIRA method is easier to be accepted by Decision Makers because it aggregates the ranks coming from several multi-criteria decision-making methods. Thus, as the application of multi-criteria methods introduces the notion of criteria weight, we

chose the Anality Hierarchy Process (AHP) method to obtain these weights. Then, the multi-criteria decision-making methods such as Weighted Sum Method (WSM), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Combined Compromise Solution (CoCoSo) were chosen to classify the students given their ease of application. We chose these four multi-criteria decision-making methods as they are widely applied in several fields [11] [12] [13] [14] [15] as well as their ability to resolve several cases of multi-criteria problems [16]-[23]. To study rank correlation, we used Kendall's rank correlation coefficient. This is how we applied MIRA to obtain the final ordering of students.

Thus, this article is structured as follows: first, we will present the MIRA method algorithm. Then, the second part is devoted to present the mode of selection of students thanks to the quota of available accommodation at the university for an academic year. The third part details the design and operation of the SAGeLogE software. The last part will be dedicated to the experimentation of SAGeLogE on the site of the Toamasina University follow up the extraction of the results. Finally, we will end this research with a discussion and conclusion.

2. Literature Review

Over the past two decades, discussion on the subject of student accommodation has intensified, focusing on student satisfaction, the way it is built, its supply on the market and its management [24]-[30]. These previous studies at various universities have shown the importance of student accommodation.

To provide opinions on the possibility of the best accommodation model, experts in the field of student housing at four higher education institutions in Bauchi State were selected [31]. The study considered student accommodation models practiced in many parts of the world. These included university-provided on-campus accommodation, off-campus accommodation, school-managed on-campus accommodation, and private off-campus accommodation. The selection criteria for these types of accommodation are academic proximity, student discipline, cost of accommodation and student safety. The aim of this study was to find out what criteria prompted students to choose their accommodation. The results showed that "academic proximity" is the most important criterion when choosing student accommodation.

Also, to highlight students' views about accommodation, a study of a model of on-campus student accommodation to guide the provision, adaptation and management of student accommodation spaces and services was carried out [32]. Thus, for students, spaces considered essential include toilets, sleeping space, kitchen, laundry and tumble dryer, infirmary, computer space and study area. These elements are all as important as the following: the existence of services such as electricity, water, security, fire safety, internet, study furniture, healthcare, generators, ventilation, maintenance, pest control, rubbish collection and cleaning. This model of student accommodation remains a challenge for universities.

To be able to manage student accommodation effectively currently, studies are focusing on the development of software. On the one hand, a description of a system supporting the management of student accommodation has been specified [33]. This system consists of housing students in special residences, each made up of several dormitories. Each building has a single gender destination, so that all the dormitories in the same building house students of the same gender. In addition, all students in each building, and therefore in each dormitory in that building, must be studying at the same undergraduate, postgraduate, or doctoral level. A dormitory is shared by several students, with the number of occupants decreasing as the level of study increases. For example, an undergraduate dormitory may be made up of 6 to 8 students, compared with 2 doctoral students. On the other hand, to solve the problem of allocating student accommodation on a university campus and streamline the decision-making process for distributing the accommodation available to each faculty, a presentation of a flexible application that performs the allocation taking into account the parameters and restrictions imposed by the university was drawn up [34]. To calculate the number of places allocated to each faculty, parameters and formulas must be entered by the user. The parameters represent the number of students, the number of places, and the number of students in their first or final year. As far as the formulas are concerned, for example for the campus of the Gheorghe Asachi Technical University in Iaşi, Romania, the formula for determining the number of places in the special-status dormitories allocated to a faculty is as follows: the total number of places in the special-status dormitories multiplied by the number of places allocated to that faculty and divided by the total number of places on the campus. In this way, the application can generate various reports and emails with the conclusions of these reports, which will be sent to the faculties.

Next, a proposal for the development of a database model and web portal for student residence enrolment management was presented [6]. The application is intended for users/students and administrators. In the process of applying for student dormitory accommodation, each student must provide data referring to academic achievement, study level, university, parents' status, household members, number of siblings and their school age, and monthly household income. There are also additional conditions that may guarantee direct allocation of accommodation in a dormitory. Once the deadline for the application process has expired, the administrator may accept or reject applications. At the end of the application process, the final ranking may be published and made accessible. Students are ranked according to the number of points they have obtained in relation to their situation. For example, if the applicant has no parents, he or she can obtain 600 additional points. If they are the child of a defender killed in the war, they can get 200 extra points. Each brother or sister adds a further 150 points. The application must also include a certain number of household residents. For household income, the number of points obtained is reduced until the total household income reaches 65% of the prescribed budget base. If the total household income is greater than 65% of the prescribed budget base, the appli-

cant will not be awarded any points in this category.

Considering the latter case, we found that the data provided by students when entering a housing application is none other than the student accommodation allocation criteria. This led us to study the accommodation allocation conditions of a number of universities [8] [9] [10] [35]-[41]. The results of this study enabled us to identify three situations. Firstly, student housing applications are assessed according to the accommodation allocation criteria. Secondly, each university has one or more criteria for prioritizing students. In addition, the decision to allocate accommodation is made by a committee made up of members who are specific to each university. As a result, we can say that the problem of allocating student accommodation is a family of problems involving conflicting decisions using several criteria to select students. It is a multi-criteria problem. Thus, to solve it an appropriate method must be applied.

3. Research Methodology

Our aim is to apply the MIRA method to the allocation of student accommodation to obtain better student rankings. The process of applying the MIRA method is divided into three stages including the use of MCDM, verification of the rank correlation coefficients then calculation of the final ranking [42]. MIRA has two variants [42], Minimum of ranks additive ($MIRA^{+}$) and Minimum of ranks subtractive ($MIRA^{-}$). Throughout this article we will choose the $MIRA^{+}$ variant because the rank correlation coefficient indicates that the used methods are positively correlated. We successively present below the chosen MCDM, the rank correlation coefficient and the $MIRA^{+}$ method algorithms.

3.1. Multi-Criteria Decision-Making Method (MCDM)

MCDM is the process of determining the best possible solution based on established criteria and problems that are common in everyday life [43]. As mentioned previously, four methods were chosen: AHP, WSM, TOPSIS and CoCoSo. We present the algorithm of these methods below.

3.1.1. Analytic Hierarchy Process (AHP)

To prioritize the structure, the Saaty scale presented in the following **Table 1** will be useful to value the priority of the criteria and the alternatives.

Table 1. Saaty scale [44].

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:

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

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

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

• matrix normalization:

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

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

• Sum of rows of the normalized matrix:

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

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

• medium consistency:

- matrix A weighting:

$$C=\sum_{i=1}^{n} a_{ij} w_i \quad \forall a_{ij} \in A \quad (4)$$

- clean vector:

$$\lambda_{\max}=\frac{1}{n}\sum_{i=1}^{n} \frac{c_i}{w_i} \quad (5)$$

• consistency index:

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

• consistency ratio:

$$CR=\frac{CI}{RI} \quad (7)$$

where RI is a random index, whose value will be presented in **Table 2** below according to the number of criteria.

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

Table 2. Random index.

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

3.1.2. Weighted Sum Method (WSM)

The weighted sum method combines all criteria into one scalar composite objective function using the weighted sum [45]. As a starting point, assume a judgment matrix A composed of m alternatives and n criteria.

$$A = \left(a_{ij}\right)_{m\times n} \tag{8}$$

Now, the process is as follows.

- matrix normalization: $B = \dfrac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \quad \forall a_{ij} \in A$ and we have

$$b_{ij} \in \text{matrix } B \tag{9}$$

- normalized matrix weighting:

$$c_i = \sum_{i=1}^{n} w_i b_{ij} \quad \text{where} \quad w_i \quad \text{is the criteria weight} \tag{10}$$

3.1.3. Technique for Order Preference by Similarity to the Ideal Solution

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 [46]. We always start with a judgment matrix A composed of m alternatives and n criteria cited in the formula (8). To achieve the solution, following steps must be followed [47]:

- matrix normalization:

$$B = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m}\left(a_{ij}\right)^2}} \tag{11}$$

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

- normalized matrix weighting:

$$X_{ij} = b_{ij} w_i \quad \text{where} \quad w_i \quad \text{is the criteria weight} \tag{12}$$

- best alternative:

$$X_j^b = \max_{i=1}^{m} X_{ij} \tag{13}$$

- worst alternative:

$$X_j^w = \min_{i=1}^{m} X_{ij} \tag{14}$$

- Euclidean distance

- compared to the best alternative:

$$d_i^b = \sqrt{\sum_{j=1}^{n}\left(X_{ij} - X_j^b\right)^2} \tag{15}$$

- compared to the worst alternative:

$$d_i^w = \sqrt{\sum_{j=1}^{n} \left(X_{ij} - X_j^w \right)^2} \tag{16}$$

- similarity to worst alternative:

$$S_i = \frac{d_i^w}{d_i^w + d_i^b} \tag{17}$$

3.1.4. Combined Compromise Solution (CoCoSo)

CoCoSo is based on an integrated simple additive weighting and exponentially weighted product model [48]. After having determined the alternatives and the associated criteria with the judgment matrix A cited in the formula (8).To achieve the solution, following steps are to be followed [48]:

- matrix normalization:

- for benefit criteria:

$$b_{ij} = \frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}} \tag{18}$$

- for cost criteria:

$$b_{ij} = \frac{\max a_{ij} - a_{ij}}{\max a_{ij} - \min a_{ij}} \tag{19}$$

- matrix weighting:

- weighted comparability sequence:

$$S_i = \sum_{i=1}^{n} b_{ij} w_i \tag{20}$$

- power weight of comparability sequences:

$$P_i = \sum_{i=1}^{n} \left(b_{ij} \right)^{w_i} \tag{21}$$

- assessment scores:

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m} \left(P_i + S_i \right)} \tag{22}$$

$$k_{ib} = \frac{P_i}{\min P_i} + \frac{S_i}{\min S_i} \tag{23}$$

$$k_{ic} = \frac{\lambda \left(S_i \right) + \left(1 - \lambda \right) \left(P_i \right)}{\lambda \max S_i + \left(1 - \lambda \right) \max P_i} \quad \text{with} \quad 0 \le \lambda \le 1 \tag{24}$$

- final score:

$$k_i = \left(k_{ia} + k_{ib} + k_{ic} \right)^{\frac{1}{3}} + \frac{1}{3} \left(k_{ia} + k_{ib} + k_{ic} \right) \tag{25}$$

3.2. Kendall's Rank Correlation

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 (u_i, v_i). An indication of the correlation between u and v can be obtained by ordering the values u_i in increasing order and by counting the number of corresponding values v_i not satisfying this order. Kendall's rank correlation is given by the formula below [49]:

$$r_k = \frac{2\left(N_c - N_d\right)}{n\left(n-1\right)} \tag{26}$$

where:

N_c: total number of concordant pair

N_d: total number of discordant pair

n: number of alternatives

The correlation coefficient r_k is a unitless value between −1 and 1. The closer r is to zero, the weaker the linear relationship. Positive values of r_k indicate a positive correlation when the values of both variables tend to increase together. Negative values of r_k 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.

3.3. Minimum of Ranks Additive (MIRA+)

Consider the judgment matrix of the correlated ranks coming from the following multi-criteria decision-making methods [42]:

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{1h} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{2h} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & r_{m3} & \cdots & r_{mh} \end{bmatrix} \tag{27}$$

where r_{mh} is the rank of alternative m for method h.

MIRA additive (MIRA$^+$) is based on the sum of the ranks obtained by each alternative for all the chosen multi-criteria decision-making methods.

$$M_m^+ = \sum_{h=1}^{n} r_{mh} \tag{28}$$

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 $A = \left(a_1, a_2, \cdots, a_n\right)$ by prioritizing those with minimum scores in lower rank. This prioritization respects the following conditions:

- $M_1^+ < M_2^+; Rank\, a_1 < Rank\, a_2$
- $M_2^+ < M_1^+; Rank\, a_2 < Rank\, a_1$
- Else $Rank\, a_2 = Rank\, a_1$

3.4. Selection of Students by the Accommodation's Quota

Once the students are ranked using the MIRA$^+$ method, we proceed to the selection of students by the accommodation quota.

The accommodation quota is a technique for equitable distribution of accommodation available within the organization responsible for allocating stu-

dent housing to the establishments that make up a university. An establishment can be a faculty or an Institute within a university. The objective is to give a proportional share to each establishment of a university according to the level of study and discipline available there. This involves dividing the total number of student accommodation available for an academic year at each level of study and each existing discipline within the establishments of a university.

During our literature review, we encountered two cases of processes for calculating student accommodation applications. The first case concerns the processing of accommodation requests in a single step who use a single group of criteria. The mode of selection of students is carried out using a group of criteria allowing the students to be ranked. The second case processes accommodation requests in two stages. First, a filtering of students necessarily following basic criteria and then ranking of the latter according to social criteria.

To do this, we first need to know the overall accommodation quota (AQ_o) for an academic year which represents the accommodation available to distribute. This involves subtracting the university's accommodation capacity (ACA) by the accommodation occupied (ACO) for an academic year. The formula below gives the overall accommodation quota:

$$AQ_o = ACA - ACO \tag{29}$$

Now we can obtain the housing quota by discipline and level of study according to the two cases cited above.

3.4.1. Single Group of Criteria

To calculate the accommodation quota by discipline and level of study (AQ_{tl}) of these organizations (universities), we need the total number of accommodation requests received (AR) and the number of accommodation requests broken down by discipline and level of study (AR_{tl}). The formula below allows you to obtain the accommodation quota by discipline and level of study (AQ_{tl}) for an organization who uses a single group of criteria:

$$AQ_{tl} = \frac{AR_{tl} \times AQ_o}{AR} \tag{30}$$

3.4.2. Two Groups of Criteria

To calculate the accommodation quota by discipline and level of study (AQ_{tl}) for an organization (universities) who uses two group of criteria, we need the total number of students admitted to the first criterion group (SA) and the number of students admitted to the first criterion group by discipline and level of study (SA_{tl}). The following formula presents the calculation method:

$$AQ_{tl} = \frac{SA_{tl} \times AQ_o}{SA} \tag{31}$$

Once we obtain this accommodation quota by discipline and level of study, we can proceed to the selection of students. This involves selecting the students ranked by the MIRA$^+$ method in relation to this number of accommodation quota by discipline and level of study. To support all these algorithms, SAGeLogE

was created. Thus, subsequently we will present how SAGeLogE selects the students receiving accommodation according to the ranking obtained by the MIRA$^+$ method and the accommodation quota by discipline and level of study.

4. SAGeLogE Software

The AHP, WSM, TOPSIS, CoCoSo and MIRA$^+$ methods are implemented in SAGeLogE, accompanied by the technique for calculating accommodation quota by discipline and level of study. SAGeLogE was developed for several reasons:

- store information regarding student accommodation requests in a single database,
- give the decision-maker the free choice of criteria for awarding student accommodation,
- prioritize criteria using the AHP method,
- rank students using multi-criteria decision-making methods like WSM, TOPSIS and CoCoSo,
- aggregate the ranks of MCDM using the MIRA$^+$ method,
- select students according to the accommodation quota by discipline and level of study,
- edit the list of students receiving accommodation according to the preferred method (WSM, TOPSIS, CoCoSo or MIRA$^+$),
- view the accommodation request statistics and the different results obtained.

Thus, we present below step by step its possibilities of SAGeLogE.

4.1. Component, Design, and Development of SAGeLogE

According to the definition of a decision support system (DSS) which was mentioned by Sprague [50], a new architecture of DSS was proposed which consists of three elements including the user interface, the Database Manager System (DBMS) and the Model Base Manager System (MBMS). In 2003, a generalized architecture of DSS was proposed by Marakas [51] composed of five distinct parts including the Database Management System (DBMS), the Model Base management system (MBMS), the Knowledge Engine (KE), user interface, and users.

SAGeLogE is a software to improve the allocation of student accommodation. It is a multi-criteria decision support system (MCDSS). A MCDSS can be defined as a computerized system that helps decision makers resolve various semi-structured and unstructured decisions involving multiple attributes or multiple objectives using data, models, and multi-criteria decision support methods [52].

Thus, to keep the specificity of a MCDSS compared to a classic DSS, we proposed a structure [4] of a MCDSS taking into account of the one proposed by Marakas [51] and the definition proposed by Eom and Lee [52] by integrating a Multi-criteria Decision-making Methods Management System (MCDMMS) to classic DSS. This means that a MCDSS has six components including: Database Management System (DBMS), the Model Base management system (MBMS),

the Knowledge Engine (KE), Multi-criteria Decision-making Methods Management System (MCDMMS), user interface, and users. Therefore, the composition of SAGeLogE is presented in Figure 1 below.

The SAGeLogE design work was carried out with the "Unified Modelling Language" tool which includes use case diagram and class diagram.

The use case diagram represents the possibility of users interacting with the system. SAGeLogE offers three possibilities to users: enter or import data, view, or display the processing results and print the various reports. The following Figure 2 shows us this use case.

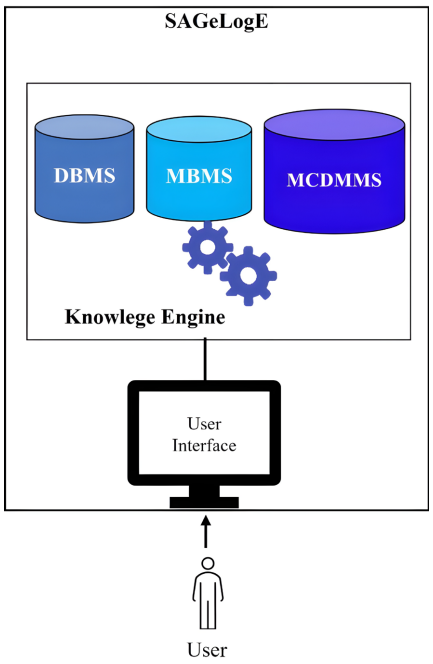


Figure 1. SAGeLogE architecture.

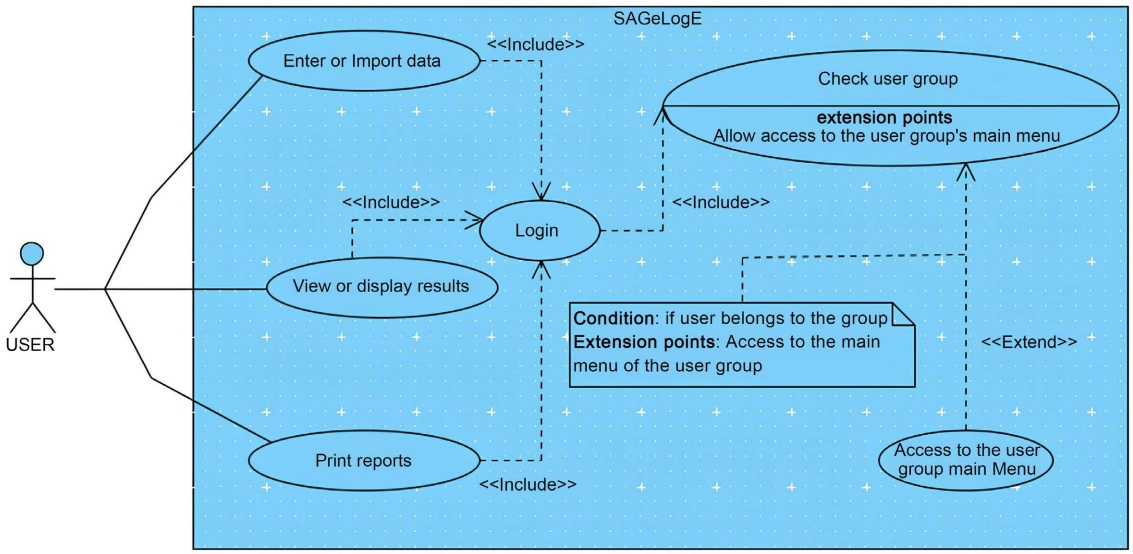


Figure 2. SAGeLogE use case diagram.

On the other hand, the class diagram describes the internal structure of SAGeLogE. In object-oriented modelling, this class diagram is considered the most important because it is a model that represents classes and their associations. For SAGeLogE, its diagram is made up of 17 interconnected classes. Considering the student accommodation allocation management rules, we present the SAGeLogE class diagram in the following Figure 3.

Following the generation of the script compared to the previous class diagram, the following Figure 4 presents the different tables of the database.

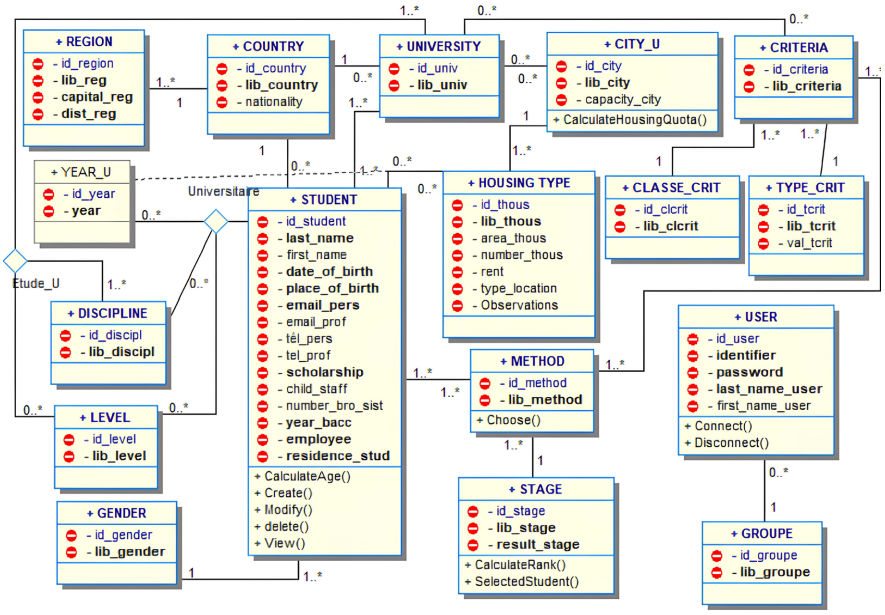


Figure 3. SAGeLogE class diagram.

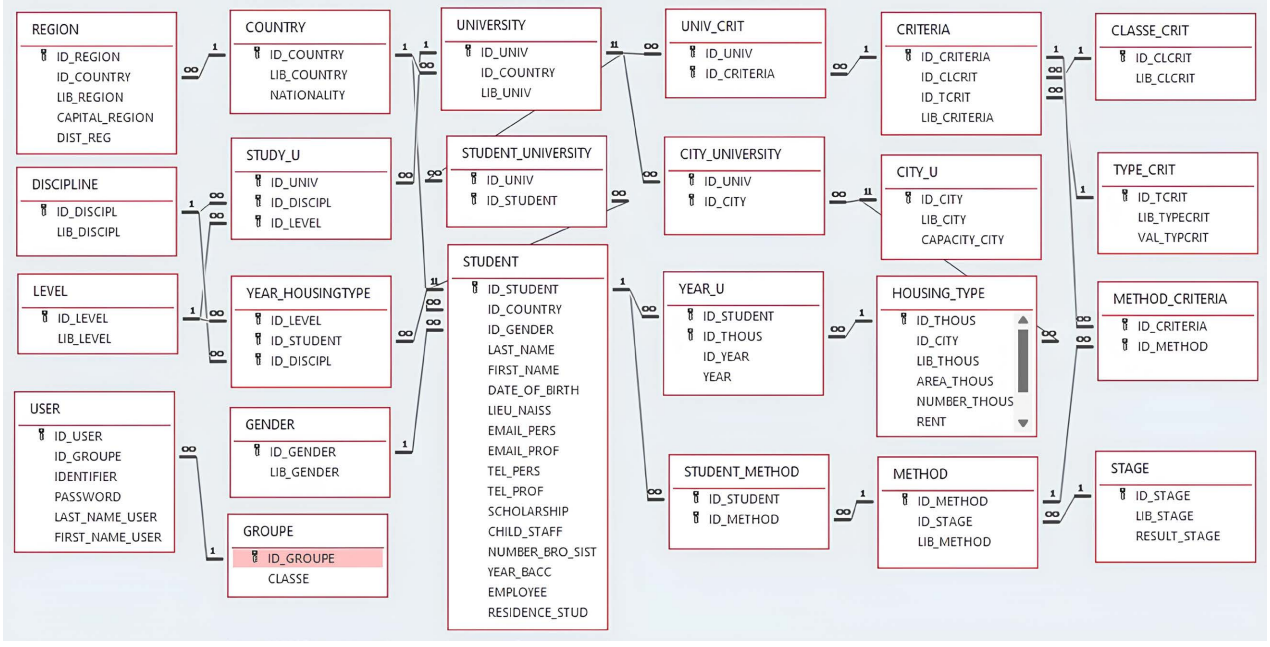


Figure 4. Relationship between SAGeLogE tables.

4.2. SAGeLogE Description

To secure data in SAGeLogE, there are four types of users including Administrator, Operator, Preparer and Decision maker. Which means, whatever the number of SAGeLogE users, they will have to group themselves into one of these four types of users. The number of members of each group is not limited. There are only four types of user groups.

In relation to these types of user's groups, there are two different functionalities: the tasks common to all users, these are the visualization and printing of the data, the results obtained and the tasks specific to each user which is the entry or data import.

The intervention of each type of user in SAGeLogE follows the protocol order that we have called "ADOP" (Administrator-Decision maker-Operator-Preparer). This means that each academic year, it is the Administrator who begins the first intervention in SAGeLogE. He enters or imports generic data such as the existing universities in a country, the existing discipline within the universities, the academic year concerned, the levels of study, the different accommodation allocation criteria in general.

Once this data is present in SAGeLogE, the Decision maker can now carry out these specific tasks including the choice of accommodation allocation criteria to be applied for an academic year and the comparison of these criteria by the AHP method to obtain their weight.

It is during the third intervention that the Preparer can enter or import the data concerning the student's situations where the identities, the discipline followed, and the accommodation requests of the students are considered.

Now we have the data that will be useful. This is how the Preparer intervenes to enter or import data concerning the study levels of each existing discipline and the different university residences followed by their accommodation capacity.

This is the reason why when using SAGeLogE, it is essential to follow this ADOP protocol order.

In relation to this situation, each user type will have to log in with their user account and password to access the specific main menu depending on the user type. **Figure 5** below shows the user authentication screen.

Once access is validated, one of the main menus shows on the figures below is displayed depending on the type of user group connected (**Figures 6-9**).

These main menus showed the different possibilities offered by SAGeLogE. Generally, there are thirty of them and are divided into three activities, namely entering, or importing data, displaying, or visualizing the results and printing the results. The difference between these main menus is the data entry, these are tasks specific to each type of user. On the other hand, visualizing and printing results are common tasks.

Now, we will present in several figures some SAGeLogE screens allowing each type of user to enter or import data to be able to use it. Also, we present a screen

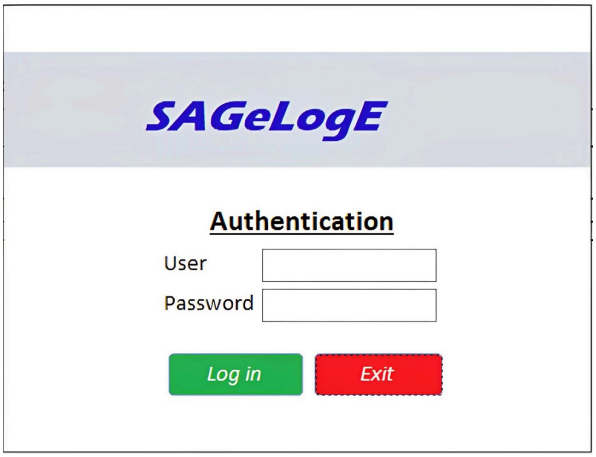


Figure 5. SAGeLogE authentication.

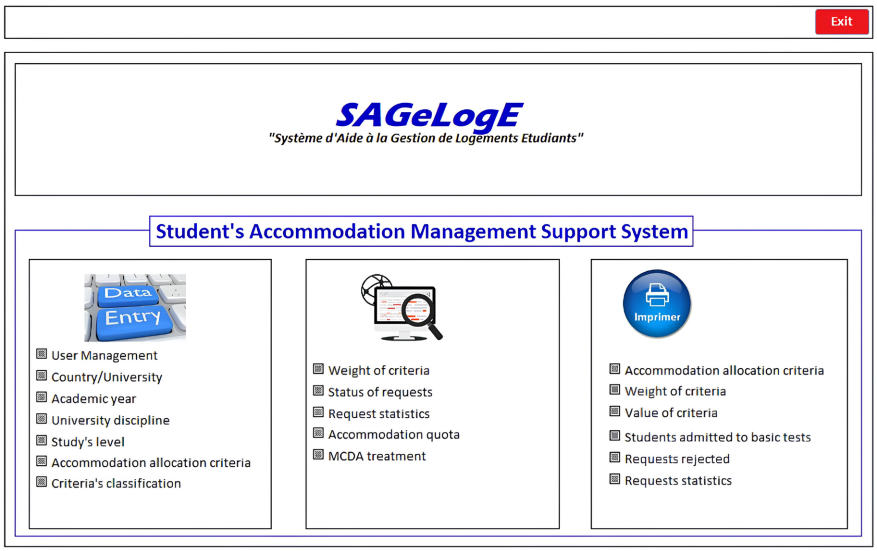


Figure 6. Administrator main menu.

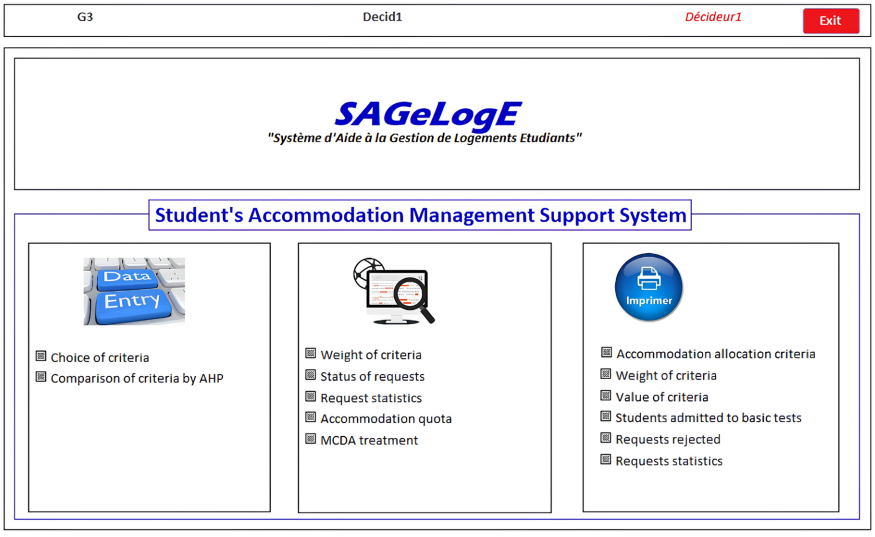


Figure 7. Decision Maker main menu.

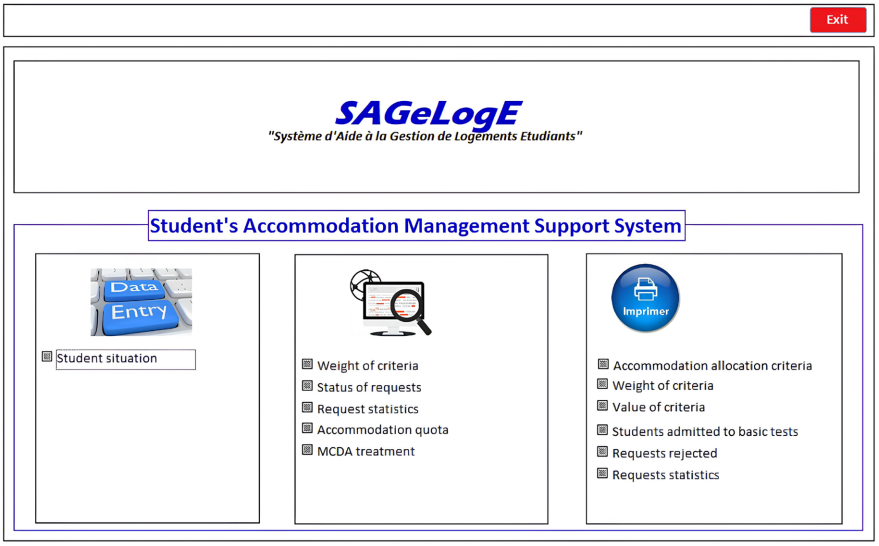


Figure 8. Operator main menu.

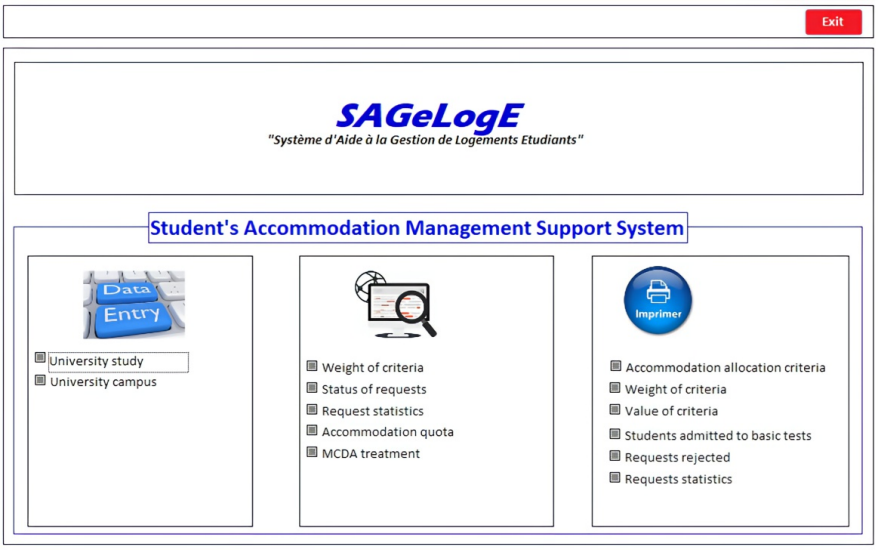


Figure 9. Preparator main menu.

allowing you to visualize the rank result of the students from each multi-criteria decision-making method installed there and the rank obtained by the MIRA method. At the same time, this last screen also gives the possibility of selecting students receiving accommodation according to the accommodation quota technique by discipline and level of study using multi-criteria decision-making methods and the MIRA method. Let's share through the screens presenting data entry for each type of user. Figure 10 below shows us the screen allowing the Administrator to enter the different criteria for allocating existing student accommodation according to the literature.

Once the different accommodation allocation criteria are entered into SAGeLogE, the Decision Maker can select the criteria to apply and assign values to each criterion. The following Figure 11 shows this possibility.

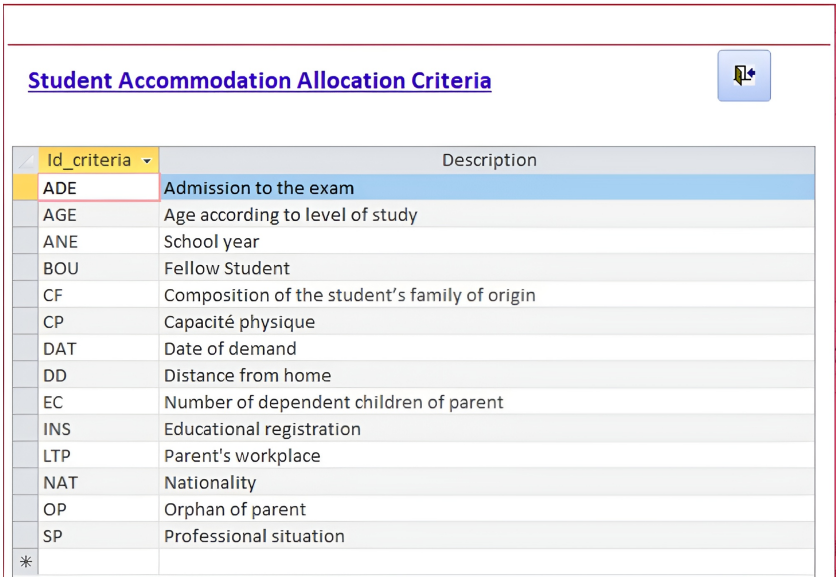


Figure 10. Entering accommodation allocation criteria by the Administrator.

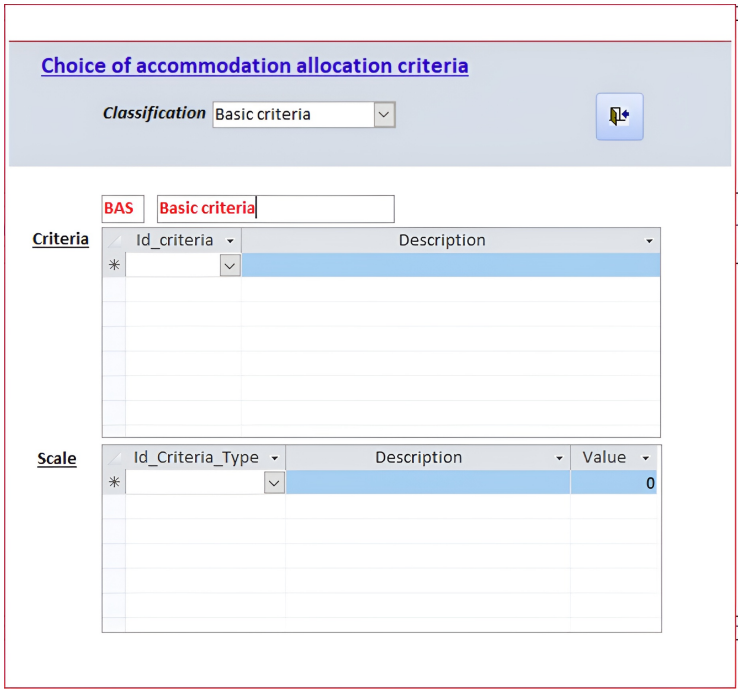


Figure 11. Choosing accommodation allocation criteria by the Decision Maker.

When the allocation criteria are entered into SAGeLogE, the Operator can now enter data concerning the students' situation. Figure 12 below shows this input screen.

As we have almost all the data, the Preparator can enter information concerning university residences managed by universities or organizations responsible for allocating student accommodation. Figure 13 below shows this screen.

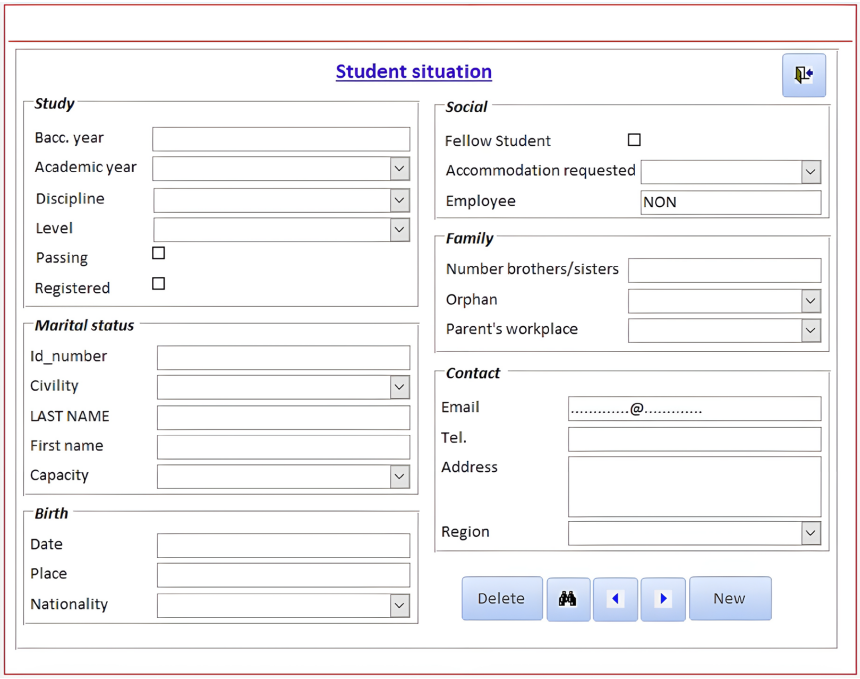


Figure 12. Entering the student situation by the Operator.

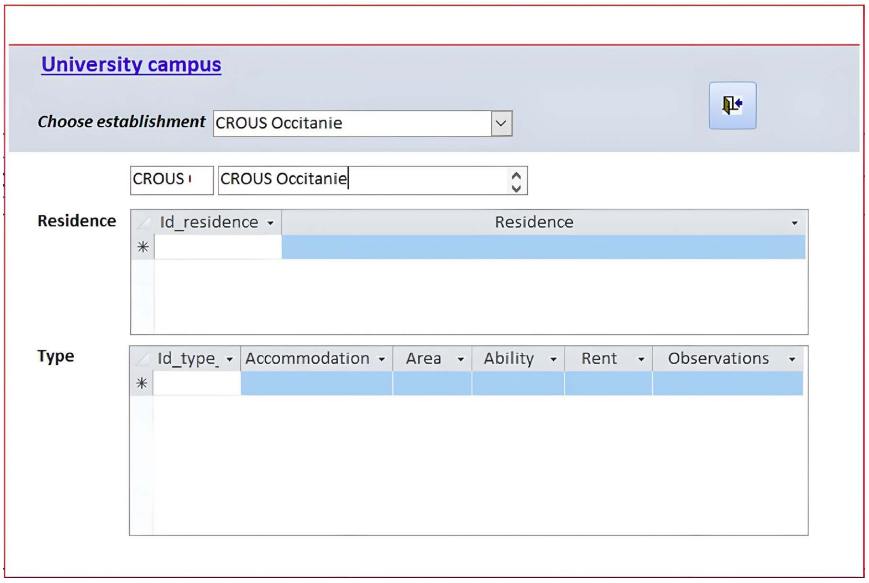


Figure 13. Entering university residences by the Preparer.

All data are currently available. It is possible for all users now to visualize the processing of the students' ranking result by the multi-criteria decision support methods and then by the MIRA method. Also, the visualization of students receiving accommodation selected by the quota calculation technique by discipline and level of study is available from Figure 14 below.

5. Experimentation and Research Results

The SAGeLogE experiment was carried out on the site of Université de Toama-

sina. In Madagascar, student accommodation is normally managed by an organization under technical supervision and attached to the Ministry responsible for higher education and Scientific Research called Regional Center for University Works (CROU). However, the CROU exist only in the capital of Madagascar. Thus, for all other Regions, a department or service attached to the University Presidency manages student accommodation. So, in the case of the Université de Toamasina, student accommodation is the responsibility of a directorate of university works (DOU) attached to the Presidency of the university.

We noted that the tasks of the leaders at the University Presidency are heavy accompanied by this management of student accommodation allocation caused by the absence of a CROU. So, it is the reason why we chose the Université de Toamasina as the first SAGeLogE experimentation site. The aim is to recommend the use of SAGeLogE to support decision-makers at the Université de Toamasina during their decision-making process for the student accommodation allocation.

For this experiment we will present the processing accommodation requests, the experiment data and the results according to SAGeLogE.

5.1. Processing Accommodation Requests

The Université de Toamasina is one of the organizations that processes student accommodation requests in two stages. Firstly, students are tested against basic criteria. At this point, they will need to meet all these criteria to move on to the second treatment process. If one or more criteria are not met by students, their applications will be rejected. Only students who have fulfilled all the basic criteria will move on to the next stage. Table 3 below presents these basic criteria and the admission requirement.

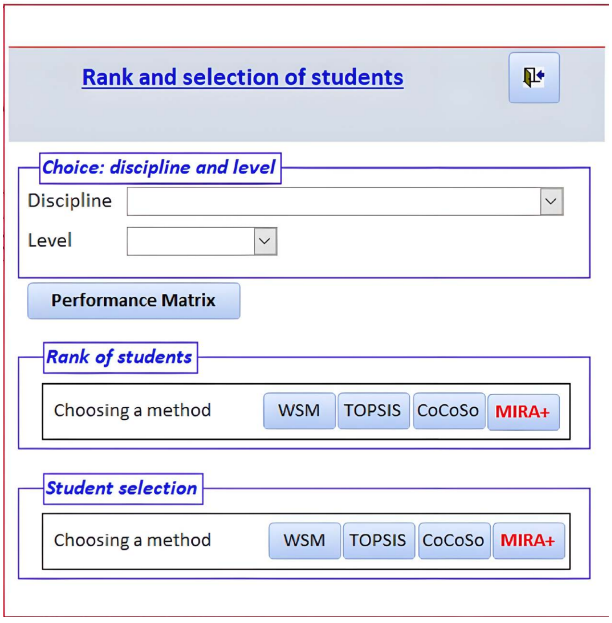


Figure 14. Ranks screen and student selection.

Table 3. Basic criteria and admission requirement.

Basic criteria	Admission requirement
Admission to exam	Admitted
Educational registration	Registered
Nationality	Malagasy
Professional situation	Unemployed
Age according to level of study	L1 ≤ 24; L2 ≤ 26; L3 ≤ 20; M1 and M2 ≤ 30

The second stage of processing accommodation requests concerns the application of social criteria. This involves ranking students according to the values of social criteria by implementing multi-criteria decision-making methods. Firstly, the AHP method to hierarchize the criteria. Secondly, the WSM, TOPSIS and CoCoSo methods to rank the students according to the specificity of each method. Thirdly, the MIRA method to aggregate the ranks obtained by the multi-criteria decision support methods. Table 4 below presents the social criteria and their values.

5.2. Experiment Data

The data relates to the 2018-2019 academic year, for which the number of student accommodation requests received is 2026. These accommodation requests are distributed by discipline and level of study within the Université de Toamasina over this academic year. The following Figure 15 presents the distribution of accommodation requests in SAGeLogE.

All these 2026 accommodation requests are entered into SAGeLogE with student information for each request. From the "Status of requests" object in the users' main menu, it's possible to view the status of accommodation requests. Once choosing this object, the screen in Figure 16 below is displayed to access the various information on the housing request.

Thus, this screen provides two viewing possibilities: the general situation (to view all request situation) and the situation by discipline and level of study (to see the details of request situation). For example, for accommodation requests received, if we click on button number 5 in the general situation column (see Figure 13), we obtain the list of 2026 housing requests received. The following Figure 17 presents the extract from the list of these 2026 housing requests received.

For the second possibility of viewing the list, it is a matter of choosing the discipline and the level of study from Figure 16 below. Then in the Discipline Level column, choose button number 1 and the list is displayed. For example, the chosen discipline is Law and the level of study is M2, the list of thirty requests is displayed as shown in Figure 18 below.

As the data available in SAGeLogE, we can move on to the different results obtained.

Table 4. Social criteria and value.

Social criteria	Value
PC[1]	Normal = 5; Disability = 10
OP[2]	None = 5; Father or Mother = 10; Father and Mother = 15
PW[3]	University = 10; Other = 5
DR[4]	By mileage
DC[5]	By number

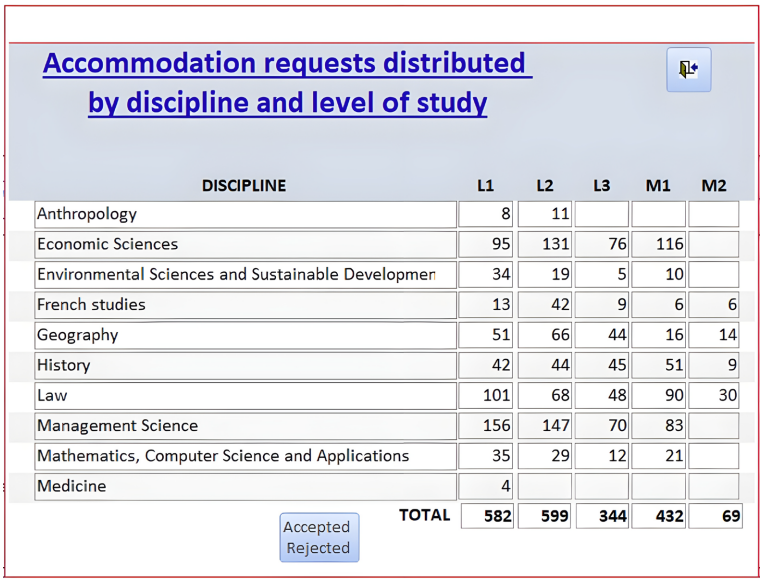


Figure 15. Accommodation requests distributed by discipline and level of study.

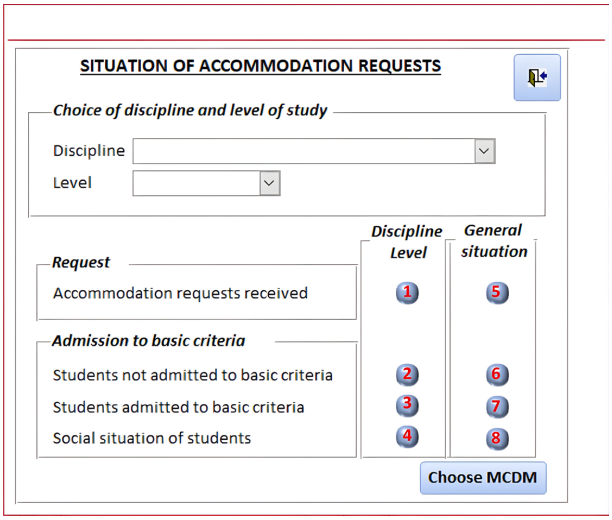
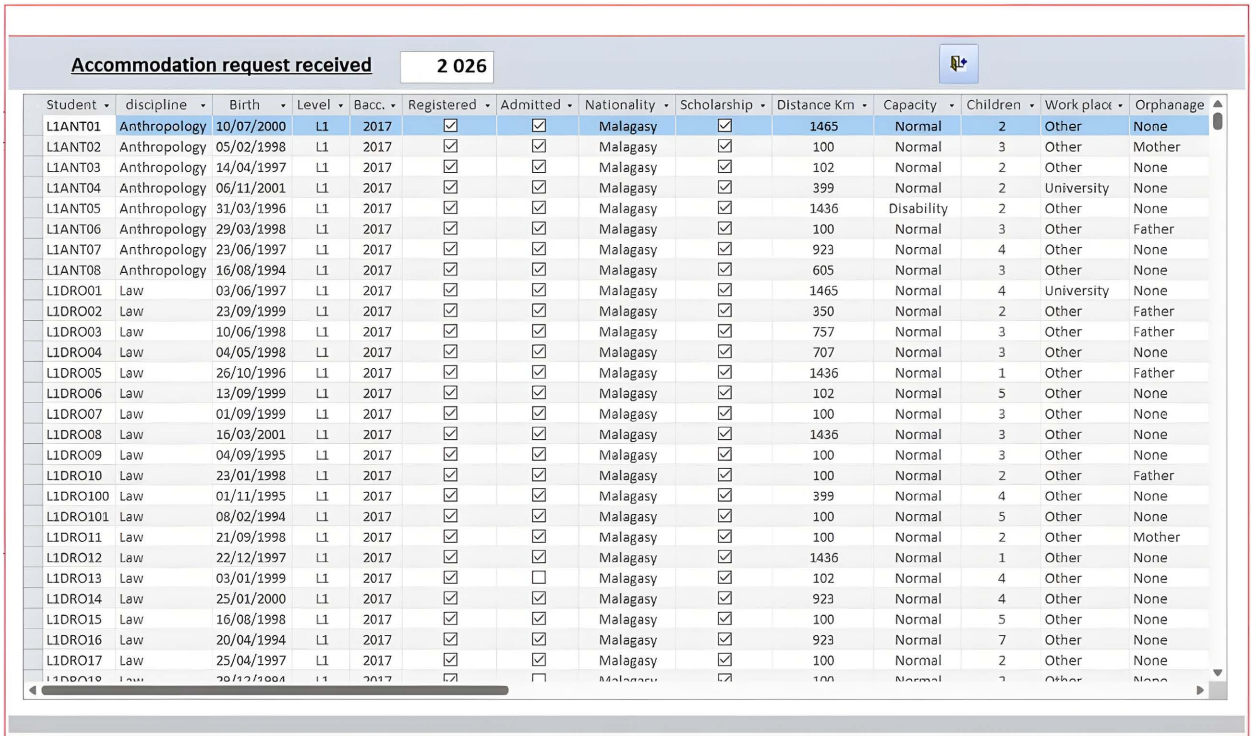


Figure 16. Status of requests.

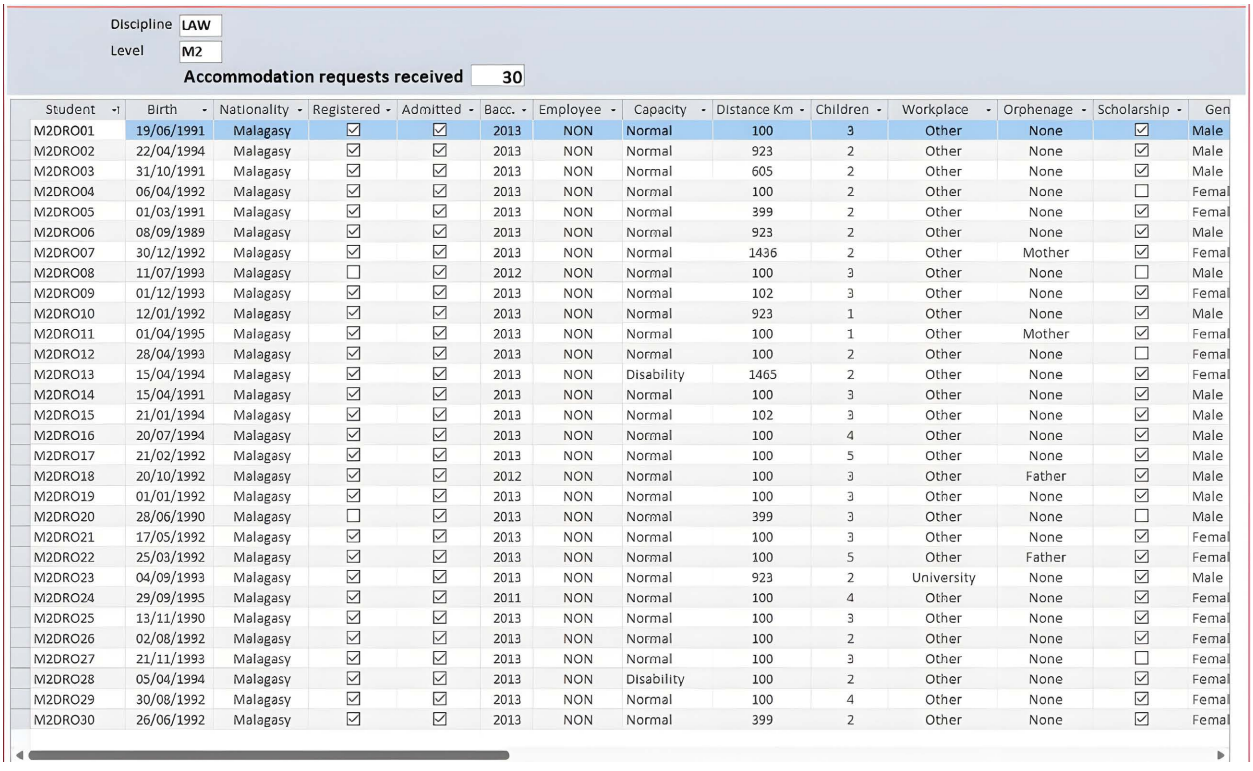
[1]Physical capacity of student.
[2]Orphanage situation of the student's parent.
[3]Parent's workplace.
[4]Distance of student's main residence from university.
[5]Number of dependent children of the parent.



Accommodation request received 2 026

Student	discipline	Birth	Level	Bacc.	Registered	Admitted	Nationality	Scholarship	Distance Km	Capacity	Children	Work place	Orphanage
L1ANT01	Anthropology	10/07/2000	L1	2017	☑	☑	Malagasy	☑	1465	Normal	2	Other	None
L1ANT02	Anthropology	05/02/1998	L1	2017	☑	☑	Malagasy	☑	100	Normal	3	Other	Mother
L1ANT03	Anthropology	14/04/1997	L1	2017	☑	☑	Malagasy	☑	102	Normal	2	Other	None
L1ANT04	Anthropology	06/11/2001	L1	2017	☑	☑	Malagasy	☑	399	Normal	2	University	None
L1ANT05	Anthropology	31/03/1996	L1	2017	☑	☑	Malagasy	☑	1436	Disability	2	Other	None
L1ANT06	Anthropology	29/03/1998	L1	2017	☑	☑	Malagasy	☑	100	Normal	3	Other	Father
L1ANT07	Anthropology	23/06/1997	L1	2017	☑	☑	Malagasy	☑	923	Normal	4	Other	None
L1ANT08	Anthropology	16/08/1994	L1	2017	☑	☑	Malagasy	☑	605	Normal	3	Other	None
L1DRO01	Law	03/06/1997	L1	2017	☑	☑	Malagasy	☑	1465	Normal	4	University	None
L1DRO02	Law	23/09/1999	L1	2017	☑	☑	Malagasy	☑	350	Normal	2	Other	Father
L1DRO03	Law	10/06/1998	L1	2017	☑	☑	Malagasy	☑	757	Normal	3	Other	Father
L1DRO04	Law	04/05/1998	L1	2017	☑	☑	Malagasy	☑	707	Normal	3	Other	None
L1DRO05	Law	26/10/1996	L1	2017	☑	☑	Malagasy	☑	1436	Normal	1	Other	Father
L1DRO06	Law	13/09/1999	L1	2017	☑	☑	Malagasy	☑	102	Normal	5	Other	None
L1DRO07	Law	01/09/1999	L1	2017	☑	☑	Malagasy	☑	100	Normal	3	Other	None
L1DRO08	Law	16/03/2001	L1	2017	☑	☑	Malagasy	☑	1436	Normal	3	Other	None
L1DRO09	Law	04/09/1995	L1	2017	☑	☑	Malagasy	☑	100	Normal	3	Other	None
L1DRO10	Law	23/01/1998	L1	2017	☑	☑	Malagasy	☑	100	Normal	2	Other	Father
L1DRO100	Law	01/11/1995	L1	2017	☑	☑	Malagasy	☑	399	Normal	4	Other	None
L1DRO101	Law	08/02/1994	L1	2017	☑	☑	Malagasy	☑	100	Normal	5	Other	None
L1DRO11	Law	21/09/1998	L1	2017	☑	☑	Malagasy	☑	100	Normal	2	Other	Mother
L1DRO12	Law	22/12/1997	L1	2017	☑	☑	Malagasy	☑	1436	Normal	1	Other	None
L1DRO13	Law	03/01/1999	L1	2017	☑	☐	Malagasy	☑	102	Normal	4	Other	None
L1DRO14	Law	25/01/2000	L1	2017	☑	☑	Malagasy	☑	923	Normal	4	Other	None
L1DRO15	Law	16/08/1998	L1	2017	☑	☑	Malagasy	☑	100	Normal	5	Other	None
L1DRO16	Law	20/04/1994	L1	2017	☑	☑	Malagasy	☑	923	Normal	7	Other	None
L1DRO17	Law	25/04/1997	L1	2017	☑	☑	Malagasy	☑	100	Normal	2	Other	None
L1DRO18	Law	28/12/1994	L1	2017	☑	☐	Malagasy	☑	100	Normal	2	Other	None

Figure 17. Extract from the 2,026 accommodation requests received in SAGeLogE.



Discipline LAW

Level M2

Accommodation requests received 30

Student	Birth	Nationality	Registered	Admitted	Bacc.	Employee	Capacity	Distance Km	Children	Workplace	Orphenage	Scholarship	Gen
M2DRO01	19/06/1991	Malagasy	☑	☑	2013	NON	Normal	100	3	Other	None	☑	Male
M2DRO02	22/04/1994	Malagasy	☑	☑	2013	NON	Normal	923	2	Other	None	☑	Male
M2DRO03	31/10/1991	Malagasy	☑	☑	2013	NON	Normal	605	2	Other	None	☑	Male
M2DRO04	06/04/1992	Malagasy	☑	☑	2013	NON	Normal	100	2	Other	None	☐	Femal
M2DRO05	01/03/1991	Malagasy	☑	☑	2013	NON	Normal	399	2	Other	None	☑	Femal
M2DRO06	08/09/1989	Malagasy	☑	☑	2013	NON	Normal	923	2	Other	None	☑	Male
M2DRO07	30/12/1992	Malagasy	☑	☑	2013	NON	Normal	1436	2	Other	Mother	☑	Femal
M2DRO08	11/07/1993	Malagasy	☐	☑	2012	NON	Normal	100	3	Other	None	☐	Male
M2DRO09	01/12/1993	Malagasy	☑	☑	2013	NON	Normal	102	3	Other	None	☑	Femal
M2DRO10	12/01/1992	Malagasy	☑	☑	2013	NON	Normal	923	1	Other	None	☑	Male
M2DRO11	01/04/1995	Malagasy	☑	☑	2013	NON	Normal	100	1	Other	Mother	☑	Femal
M2DRO12	28/04/1993	Malagasy	☑	☑	2013	NON	Normal	100	2	Other	None	☐	Femal
M2DRO13	15/04/1994	Malagasy	☑	☑	2013	NON	Disability	1465	2	Other	None	☑	Femal
M2DRO14	15/04/1991	Malagasy	☑	☑	2013	NON	Normal	100	3	Other	None	☑	Male
M2DRO15	21/01/1994	Malagasy	☑	☑	2013	NON	Normal	102	3	Other	None	☑	Male
M2DRO16	20/07/1994	Malagasy	☑	☑	2013	NON	Normal	100	4	Other	None	☑	Male
M2DRO17	21/02/1992	Malagasy	☑	☑	2013	NON	Normal	100	5	Other	None	☑	Male
M2DRO18	20/10/1992	Malagasy	☑	☑	2012	NON	Normal	100	3	Other	Father	☑	Male
M2DRO19	01/01/1992	Malagasy	☑	☑	2013	NON	Normal	100	3	Other	None	☑	Male
M2DRO20	28/06/1990	Malagasy	☐	☑	2013	NON	Normal	399	3	Other	None	☐	Male
M2DRO21	17/05/1992	Malagasy	☑	☑	2013	NON	Normal	100	3	Other	None	☑	Femal
M2DRO22	25/03/1992	Malagasy	☑	☑	2013	NON	Normal	100	5	Other	Father	☑	Femal
M2DRO23	04/09/1993	Malagasy	☑	☑	2013	NON	Normal	923	2	University	None	☑	Male
M2DRO24	29/09/1995	Malagasy	☑	☑	2011	NON	Normal	100	4	Other	None	☑	Femal
M2DRO25	13/11/1990	Malagasy	☑	☑	2013	NON	Normal	100	3	Other	None	☑	Femal
M2DRO26	02/08/1992	Malagasy	☑	☑	2013	NON	Normal	100	2	Other	None	☑	Femal
M2DRO27	21/11/1993	Malagasy	☑	☑	2013	NON	Normal	100	3	Other	None	☐	Femal
M2DRO28	05/04/1994	Malagasy	☑	☑	2013	NON	Disability	100	2	Other	None	☑	Femal
M2DRO29	30/08/1992	Malagasy	☑	☑	2013	NON	Normal	100	4	Other	None	☑	Femal
M2DRO30	26/06/1992	Malagasy	☑	☑	2013	NON	Normal	399	2	Other	None	☑	Femal

Figure 18. List of 30 accommodation requests received in M2 Law.

5.3. Experiment Results

We successively present the results obtained during the SAGeLogE experimenta-

tion namely the result of the test for the basic criterion, the hierarchy of social criteria by the AHP method, the ranking of students by the WSM, TOPSIS and CoCoSo methods according to the social criteria, the final rank by the MIRA$^+$ method, the accommodation quota by mention and level of study and the selection of student beneficiaries of accommodation.

5.3.1. Result of the Test for the Basic Criterion

After applying the test to the basic criterion (see Table 3), two situations are obtained including admitted students to the basic criterion and rejected accommodation requests. Thus, of the 2026 accommodation requests received, 1804 students met all the basic criteria, therefore their accommodation requests are received, and 222 students did not meet one or more basic criteria, therefore their accommodation requests were rejected. Table 5 below presents these situations.

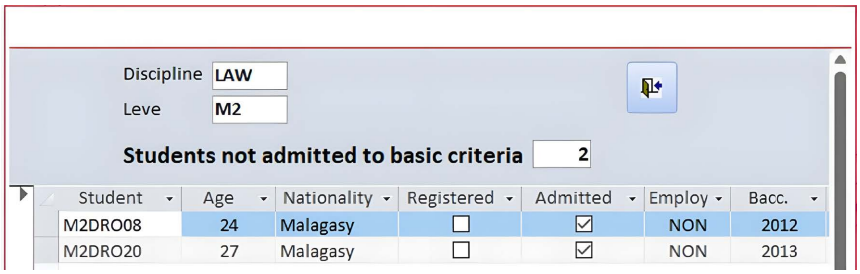
Table 5. Summary of requests by discipline and level of study.

Discipline	Level	Received	Accepted	Rejected	Discipline	Level	Received	Accepted	Rejected
Economic Sciences	L1	95	80	15	Anthropology	L1	8	8	0
	L2	131	121	10		L2	11	10	1
	L3	76	71	5	Law	L1	101	79	22
	M1	116	101	15		L2	68	62	6
Environmental Sciences and Sustainable Development	L1	34	29	5		L3	48	43	5
	L2	19	18	1		M1	90	77	13
	L3	5	5	0		M2	30	28	2
	M1	10	9	1	Management Science	L1	156	143	13
French studies	L1	13	10	3		L2	147	143	4
	L2	42	34	8		L3	70	61	9
	L3	9	7	2		M1	83	81	2
	M1	6	5	1	Mathematics, Computer Science and Applications	L1	35	27	8
	M2	6	6	0		L2	29	26	3
Geography	L1	51	49	2		L3	12	11	1
	L2	66	47	19		M1	21	16	5
	L3	44	40	4	Medicine	L1	4	3	1
	M1	16	14	2	Philosophy	L1	43	41	2
	M2	14	11	3		L2	42	39	3
History	L1	42	36	6		L3	35	31	4
	L2	44	39	5		M1	39	37	2
	L3	45	41	4		M2	10	9	1
	M1	51	48	3	**TOTAL**		**2026**	**1804**	**222**
	M2	9	8	1					

Now, let's take the case of M2 Law students who are among the thirty requests received. The previous Table 4 shows us that 28 requests for student accommodation are accepted compared to 2 requests rejected. We will present in successive figures the list of the 2 students who did not fulfil the basic criteria (Figure 19) and the list of the 28 students who fulfil them (Figure 20).

We noticed that these 2 students did not meet one of the basic criteria because they are not registered in M2. This is why their requests for student accommodation are rejected because all the basic criteria must be met for the requests to be accepted.

28 accommodations applications were accepted because the students meet all the basic criteria.



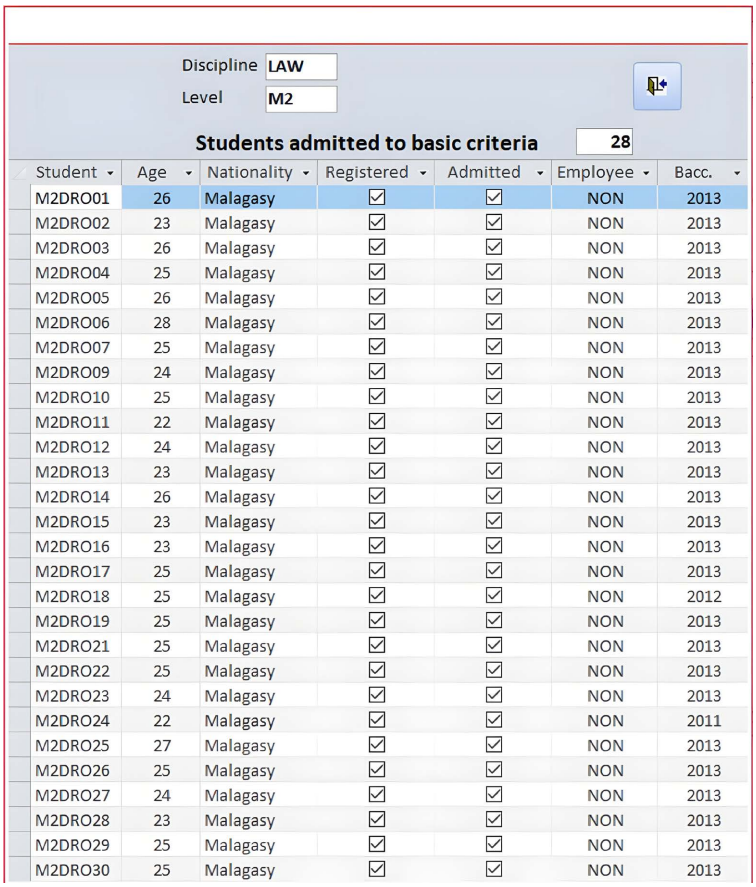
Discipline LAW

Leve M2

Students not admitted to basic criteria 2

Student	Age	Nationality	Registered	Admitted	Employ	Bacc.
M2DRO08	24	Malagasy	☐	☑	NON	2012
M2DRO20	27	Malagasy	☐	☑	NON	2013

Figure 19. Students in M2 Law not admitted to basic criteria.



Discipline LAW

Level M2

Students admitted to basic criteria 28

Student	Age	Nationality	Registered	Admitted	Employee	Bacc.
M2DRO01	26	Malagasy	☑	☑	NON	2013
M2DRO02	23	Malagasy	☑	☑	NON	2013
M2DRO03	26	Malagasy	☑	☑	NON	2013
M2DRO04	25	Malagasy	☑	☑	NON	2013
M2DRO05	26	Malagasy	☑	☑	NON	2013
M2DRO06	28	Malagasy	☑	☑	NON	2013
M2DRO07	25	Malagasy	☑	☑	NON	2013
M2DRO09	24	Malagasy	☑	☑	NON	2013
M2DRO10	25	Malagasy	☑	☑	NON	2013
M2DRO11	22	Malagasy	☑	☑	NON	2013
M2DRO12	24	Malagasy	☑	☑	NON	2013
M2DRO13	23	Malagasy	☑	☑	NON	2013
M2DRO14	26	Malagasy	☑	☑	NON	2013
M2DRO15	23	Malagasy	☑	☑	NON	2013
M2DRO16	23	Malagasy	☑	☑	NON	2013
M2DRO17	25	Malagasy	☑	☑	NON	2013
M2DRO18	25	Malagasy	☑	☑	NON	2012
M2DRO19	25	Malagasy	☑	☑	NON	2013
M2DRO21	25	Malagasy	☑	☑	NON	2013
M2DRO22	25	Malagasy	☑	☑	NON	2013
M2DRO23	24	Malagasy	☑	☑	NON	2013
M2DRO24	22	Malagasy	☑	☑	NON	2011
M2DRO25	27	Malagasy	☑	☑	NON	2013
M2DRO26	25	Malagasy	☑	☑	NON	2013
M2DRO27	24	Malagasy	☑	☑	NON	2013
M2DRO28	23	Malagasy	☑	☑	NON	2013
M2DRO29	25	Malagasy	☑	☑	NON	2013
M2DRO30	25	Malagasy	☑	☑	NON	2013

Figure 20. Students in M2 Law admitted to basic criteria.

We noticed that these 28 students met all the basic criteria including age less than 30 years, Malagasy nationality, admitted and registered in M2, non-employed and they obtained their baccalaureate in 2013. This is why they are admitted to the basic criterion test. Now, as we have the situation of the students admitted to the basic criteria, we can proceed to rank the students using multi-criteria decision-making methods.

5.3.2. Ranking of Students Admitted to Basic Criteria by MIRA+ Method

To be able to rank admitted students according to the basic criteria, we need the performance matrix and the weight of social criteria. This is how we will successively present how to obtain the decision matrix and the weights of the criteria to rank the students.

• ***Performance matrix***

Generally, we have 1,804 accepted accommodation requests broken down by discipline and level of study. As the processing of files is done by discipline and level of study, each discipline and level of study has its own decision matrix depending on the number of requests accepted (see **Figure 16**). The decision matrix is obtained from the social situation of the students. At this stage, it is the social criteria that are implemented. Remember that there are five social criteria (see **Table 4**). As sample, the following **Figure 21** presents the social situation of the 28 students in M2 Law admitted to the basic criteria.

Social situation of students admitted to basic criteria: 28 | Discipline: LAW | Level: M2

Student	PC	DR	DC	PW	OP
M2DRO01	Normal	Atsinanana	3	Other	None
M2DRO02	Normal	Boeny	2	Other	None
M2DRO03	Normal	Vatovavy Fitovinany	2	Other	None
M2DRO04	Normal	Atsinanana	2	Other	None
M2DRO05	Normal	Alaotra Mangoro	2	Other	None
M2DRO06	Normal	Boeny	2	Other	None
M2DRO07	Normal	Sava	2	Other	Mother
M2DRO09	Normal	Analanjirofo	3	Other	None
M2DRO10	Normal	Boeny	1	Other	None
M2DRO11	Normal	Atsinanana	1	Other	Mother
M2DRO12	Normal	Atsinanana	2	Other	None
M2DRO13	Disability	Diana	2	Other	None
M2DRO14	Normal	Atsinanana	3	Other	None
M2DRO15	Normal	Analanjirofo	3	Other	None
M2DRO16	Normal	Atsinanana	4	Other	None
M2DRO17	Normal	Atsinanana	5	Other	None
M2DRO18	Normal	Atsinanana	3	Other	Father
M2DRO19	Normal	Atsinanana	3	Other	None
M2DRO21	Normal	Atsinanana	3	Other	None
M2DRO22	Normal	Atsinanana	5	Other	Father
M2DRO23	Normal	Boeny	2	University	None
M2DRO24	Normal	Atsinanana	4	Other	None
M2DRO25	Normal	Atsinanana	3	Other	None
M2DRO26	Normal	Atsinanana	2	Other	None
M2DRO27	Normal	Atsinanana	3	Other	None
M2DRO28	Disability	Atsinanana	2	Other	None
M2DRO29	Normal	Atsinanana	4	Other	None
M2DRO30	Normal	Alaotra Mangoro	2	Other	None

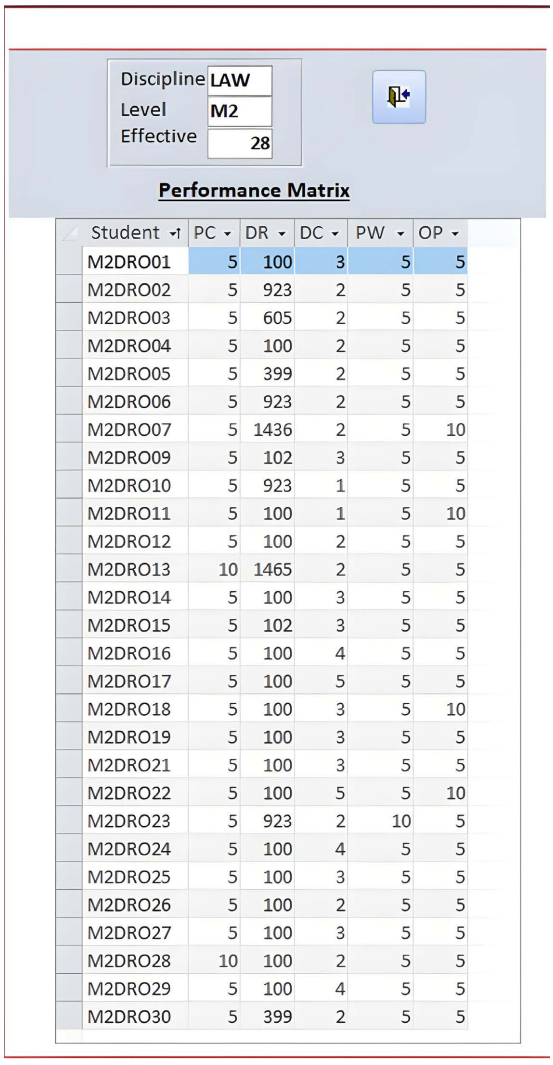
Figure 21. Social situation of students in M2 Law admitted to the basic.

In relation to this social situation, the following Figure 22 presents the social situation in value. This is the performance matrix.

Now, we will move on to the process of calculating the weight of social criteria before proceeding with the application of multi-criteria decision-making methods.

• ***Weight of criteria by the AHP method***

Comparing the criteria is the task of the decision-maker. This involves applying the AHP multi-criteria decision-making method. Here, the decision-maker uses the Saaty scale (see Table 1) to compare the social criteria against them. The following figure presents two screens: on the left gives the comparison of the criteria carried out by the decision-maker and on the right the result of the comparison which shows the weight of the criteria followed by the verification of consistencies. Once the comparison has been made by the decision-maker, simply click on the "Weight" button on the screen on the left to view the result of the weight of the criteria on the screen on the right of Figure 23.



Student	PC	DR	DC	PW	OP
M2DRO01	5	100	3	5	5
M2DRO02	5	923	2	5	5
M2DRO03	5	605	2	5	5
M2DRO04	5	100	2	5	5
M2DRO05	5	399	2	5	5
M2DRO06	5	923	2	5	5
M2DRO07	5	1436	2	5	10
M2DRO09	5	102	3	5	5
M2DRO10	5	923	1	5	5
M2DRO11	5	100	1	5	10
M2DRO12	5	100	2	5	5
M2DRO13	10	1465	2	5	5
M2DRO14	5	100	3	5	5
M2DRO15	5	102	3	5	5
M2DRO16	5	100	4	5	5
M2DRO17	5	100	5	5	5
M2DRO18	5	100	3	5	10
M2DRO19	5	100	3	5	5
M2DRO21	5	100	3	5	5
M2DRO22	5	100	5	5	10
M2DRO23	5	923	2	10	5
M2DRO24	5	100	4	5	5
M2DRO25	5	100	3	5	5
M2DRO26	5	100	2	5	5
M2DRO27	5	100	3	5	5
M2DRO28	10	100	2	5	5
M2DRO29	5	100	4	5	5
M2DRO30	5	399	2	5	5

Figure 22. Performance matrix of the 28 students in M2 Law.

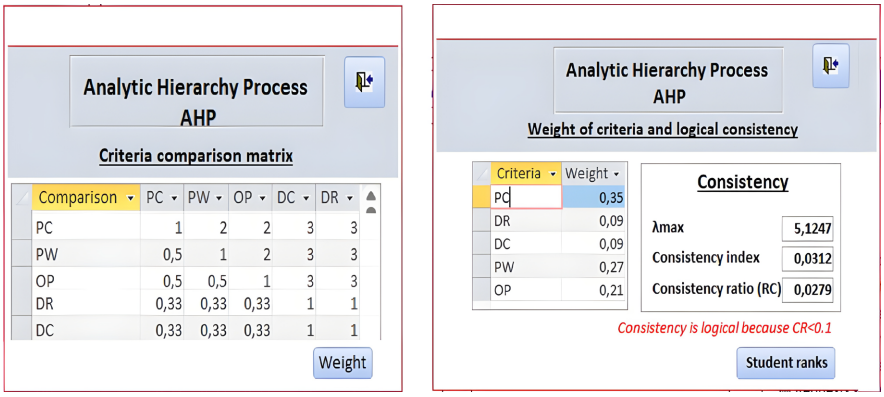


Figure 23. Comparison of criteria by AHP and its weights.

We now have all the necessary elements to rank the students. According to the MIRA$^+$ method, the ranking of students using multi-criteria decision-making methods begins the process.

• ***Rank of students according to MCDM***

As previously mentioned, we always consider the case of M2 Law students. **Figure 24** below summarizes three different screens of SAGeLogE which gives the ranks obtained respectively by the WSM, TOPSIS and CoCoSo methods.

We note that the ranks obtained by these three methods are different depending on their specificity. Before applying the MIRA$^+$ method, we first check the correlation of the ranks resulting from these WSM, TOPSIS and CoCoSo methods. The following **Figure 25** presents the result of Kendall's rank correlation coefficient.

As the correlation coefficients are all positive and tend towards 1, those which mean that the WSM, TOPSIS and CoCoSo methods have the same meaning. Thus, we can apply the MIRA$^+$ method.

• ***Rank of students using the MIRA$^+$ method***

The MIRA$^+$ method will now aggregate the different ranks obtained by the WSM, TOPSIS and CoCoSo methods. This is a satisfactory rank compared to the difference produced by the three multi-criteria decision-making methods. The following **Figure 26** presents the rank of students in M2 Law. This rank is followed by its Kendall correlation coefficients compared to the WSM, TOPSIS and CoCoSo methods to validate the rank obtained.

• ***Selection of students according to the accommodation quota***

Remember that we have received a total of 2026 student accommodation requests, including 222 requests rejected and 1804 requests accepted (see **Figure 16**). For the 2018-2019 academic year, the availability of accommodation to be distributed to students is 1249. However, 1249 students must be selected from among the 1804 students admitted according to the basic criteria. This is why we recommend the accommodation quota technique by discipline and level of study to fairly distribute these accommodations available to existing discipline and levels of study within the university. Thus, the following **Table 6** presents the ac-

commodation quota by discipline and level of study in relation to the requests accepted for this academic year.

Weighted Sum Method WSM

Discipline: LAW
Level: M2
Effective: 28
Quota: 19

Student scoring and ranking

Student	Score	Rank
M2DRO13	0,0549	1
M2DRO07	0,0496	2
M2DRO23	0,0477	3
M2DRO28	0,0425	4
M2DRO22	0,041	5
M2DRO18	0,0386	6
M2DRO02	0,0384	7
M2DRO06	0,0384	7
M2DRO10	0,0372	9
M2DRO11	0,0362	10
M2DRO03	0,0355	11
M2DRO17	0,0345	12
M2DRO05	0,0336	13
M2DRO30	0,0336	13
M2DRO24	0,0333	15
M2DRO16	0,0333	15
M2DRO29	0,0333	15
M2DRO09	0,0321	18
M2DRO01	0,0321	18
M2DRO15	0,0321	18
M2DRO19	0,0321	18
M2DRO21	0,0321	18
M2DRO25	0,0321	18
M2DRO27	0,0321	18
M2DRO14	0,0321	18
M2DRO12	0,0309	26
M2DRO04	0,0309	26
M2DRO26	0,0309	26

Technique for Order of Preference by Similarity to Ideal Solution TOPSIS

Discipline: LAW
Level: M2
Effective: 28
Quota: 19

Students scoring and ranking

Student	Score	Rank
M2DRO13	0,7832	1
M2DRO07	0,7299	2
M2DRO23	0,5512	3
M2DRO06	0,5155	4
M2DRO02	0,5155	4
M2DRO10	0,5137	6
M2DRO03	0,3311	7
M2DRO28	0,2156	8
M2DRO05	0,2004	9
M2DRO30	0,2004	9
M2DRO22	0,1563	11
M2DRO18	0,1432	12
M2DRO11	0,1381	13
M2DRO17	0,0832	14
M2DRO24	0,0637	15
M2DRO16	0,0637	15
M2DRO29	0,0637	15
M2DRO09	0,0434	18
M2DRO01	0,0434	18
M2DRO15	0,0434	18
M2DRO19	0,0434	18
M2DRO21	0,0434	18
M2DRO25	0,0434	18
M2DRO27	0,0434	18
M2DRO14	0,0434	18
M2DRO12	0,0221	26
M2DRO04	0,0221	26
M2DRO26	0,0221	26

Combined Compromise Solution CoCoSo

Discipline: LAW
Level: M2
Effective: 28
Quota: 19

Students scoring and ranking

Student	Score	Rank
M2DRO13	9,519	1
M2DRO23	7,6391	2
M2DRO28	7,3365	3
M2DRO07	7,2498	4
M2DRO22	6,2716	5
M2DRO18	5,5083	6
M2DRO11	4,0895	7
M2DRO02	2,553	8
M2DRO06	2,553	8
M2DRO03	2,1766	10
M2DRO17	2,174	11
M2DRO05	1,9201	12
M2DRO30	1,9201	12
M2DRO24	1,7914	14
M2DRO16	1,7914	14
M2DRO29	1,7914	14
M2DRO09	1,7897	17
M2DRO15	1,7897	17
M2DRO10	1,5631	19
M2DRO01	1,3993	20
M2DRO19	1,3993	20
M2DRO21	1,3993	20
M2DRO25	1,3993	20
M2DRO27	1,3993	20
M2DRO14	1,3993	20
M2DRO12	0,9871	26
M2DRO04	0,9871	26
M2DRO26	0,9871	26

Figure 24. Rank of students by WSM, TOPSIS and CoCoSo methods.

```
        Kendall's rank correlation tau

data:  WSM and TOPSIS
z = 6.1024, p-value = 1.045e-09
alternative hypothesis: true tau is not equal to 0
sample estimates:
     tau
0.877193

        Kendall's rank correlation tau

data:  WSM and CoCoSo
z = 6.3422, p-value = 2.265e-10
alternative hypothesis: true tau is not equal to 0
sample estimates:
     tau
0.902433

        Kendall's rank correlation tau

data:  TOPSIS and CoCoSo
z = 5.4939, p-value = 3.932e-08
alternative hypothesis: true tau is not equal to 0
sample estimates:
      tau
0.7817254
```

Figure 25. Kendall's rank correlation coefficient for WSM, TOPSIS and CoCoSo.

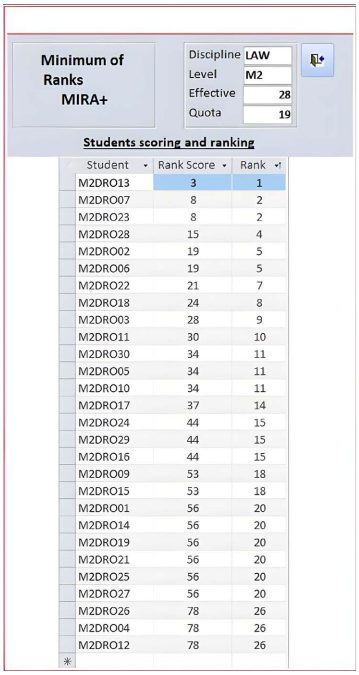


Figure 26. Rank of M2 Law students by the MIRA$^+$ method and its Kendall's correlation.

Table 6. Student accommodation quota by discipline and quota.

Discipline	Level	Accepted	Quota	Discipline	Level	Accepted	Quota
Economic Sciences	L1	80	55	Anthropology	L1	8	6
	L2	121	84		L2	10	7
	L3	71	49	Law	L1	79	55
	M1	101	70		L2	62	43
Environmental Sciences and Sustainable Development	L1	29	20		L3	43	30
	L2	18	12		M1	77	53
	L3	5	3		M2	28	19
	M1	9	6	Management Science	L1	143	99
French studies	L1	10	7		L2	143	99
	L2	34	24		L3	61	42
	L3	7	5		M1	81	56
	M1	5	3	Mathematics, Computer Science and Applications	L1	27	19
	M2	6	4		L2	26	18
Geography	L1	49	34		L3	11	8
	L2	47	33		M1	16	11
	L3	40	28	Medicine	L1	3	2
	M1	14	10	Philosophy	L1	41	28
	M2	11	8		L2	39	27
History	L1	36	25		L3	31	21
	L2	39	27		M1	37	26
	L3	41	28		M2	9	6
	M1	48	33	**TOTAL**		**1804**	**1249**
	M2	8	6				

Now in relation to the rank of students obtained by the MIRA$^+$ method, SA-GeLogE will select the students receiving accommodation according to this accommodation quota. If we take the case of M2 Law students, the accepted requests number 28 while the quota of available accommodation is 19. Thus, SA-GeLogE extracts the list of the first 19 students according to the ranking carried out by the MIRA$^+$ method. Figure 27 below presents the list of these students for the case of M2 Law.

REPUBLIC OF MADAGASCAR
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MINISTRY OF HIGHER EDUCATION
AND SCIENTIFIC RESEARCH
****
UNIVERSITÉ DE TOAMASINA
****
DIRECTORATE OF UNIVERSITY WORKS
ACCOMMODATION SERVICE

List of students receiving accommodation

Selection method : MIRA+

M2 Law

Rank	Student	Date of Birth	FIRST NAME	LAST NAME
1	M2DRO13	15/04/1994		
2	M2DRO23	04/09/1993		
2	M2DRO07	30/12/1992		
4	M2DRO28	05/04/1994		
5	M2DRO06	08/09/1989		
5	M2DRO02	22/04/1994		
7	M2DRO22	25/03/1992		
8	M2DRO18	20/10/1992		
9	M2DRO03	31/10/1991		
10	M2DRO11	01/04/1995		
11	M2DRO05	01/03/1991		
11	M2DRO30	26/06/1992		
11	M2DRO10	12/01/1992		
14	M2DRO17	21/02/1992		
15	M2DRO16	20/07/1994		
15	M2DRO24	29/09/1995		
15	M2DRO29	30/08/1992		
18	M2DRO09	01/12/1993		
18	M2DRO15	21/01/1994		

Ended this list at the number of nineteen (19) students selecte

Toamasina, the

The Head of accommodation Service

The Director of University Works

Figure 27. Selection of M2 Law students receiving accommodation by MIRA$^+$ method.

6. Discussion and Conclusion

6.1. Discussion

Following our literature review, universities are using the classic technique to rank students to select them. This technique is simply the sum of the marks obtained by each student according to the value of the criteria chosen by the university. This means that the students with the highest marks are placed at the top. In the case of M2 Law students, we will rank them using the classic technique used by the university. Table 7 below shows the student performance matrix followed by their rankings using the classic method, and MIRA$^+$.

Table 7. Performance matrix and students' ranks.

Student	Performance matrix					Rank	
	PC	DR	DC	PW	OP	University	MIRA$^+$
M2DRO13	10	1465	2	5	5	1	1
M2DRO07	5	1436	2	5	10	2	2
M2DRO23	5	923	2	10	5	3	2
M2DRO02	5	923	2	5	5	4	5
M2DRO06	5	923	2	5	5	4	5
M2DRO10	5	923	1	5	5	6	11
M2DRO03	5	605	2	5	5	7	9
M2DRO05	5	399	2	5	5	8	11
M2DRO30	5	399	2	5	5	8	11
M2DRO22	5	100	5	5	10	10	7
M2DRO18	5	100	3	5	10	11	8
M2DRO28	10	100	2	5	5	12	4
M2DRO11	5	100	1	5	10	13	10
M2DRO09	5	102	3	5	5	14	18
M2DRO15	5	102	3	5	5	14	18
M2DRO17	5	100	5	5	5	14	14
M2DRO16	5	100	4	5	5	17	15
M2DRO24	5	100	4	5	5	17	15
M2DRO29	5	100	4	5	5	17	15
M2DRO01	5	100	3	5	5	20	20
M2DRO14	5	100	3	5	5	20	20
M2DRO19	5	100	3	5	5	20	20
M2DRO21	5	100	3	5	5	20	20
M2DRO25	5	100	3	5	5	20	20
M2DRO27	5	100	3	5	5	20	20
M2DRO04	5	100	2	5	5	26	26
M2DRO12	5	100	2	5	5	26	26
M2DRO26	5	100	2	5	5	26	26

The DR criterion relates to the distance by kilometer that the student lives from the university. We note that the ranking technique used by the university means that only students who live a long way from the university are placed at the top of the list, regardless of the value of the other criteria. However, a problem arises because the university's policy is to give priority to students with physical disabilities. In this table, this criterion is presented by CP. Normally, according to this policy, students with a CP value of 10 are given priority. However, here we see that the M2DRO28 student is ranked 12th according to the university's method. We can therefore say that this technique does not achieve the university's policy. On the other hand, using the MIRA$^+$ method, it is not only students who live far from the university (the most important DR) who are ranked first. For example, MIRA$^+$ was able to recover the M2DRO28 student in 4th place even though he lives close to the university (DR = 100) compared to the other students. We can say that MIRA$^+$ is more favorable than the method used by the university because the student M2DRO28 has a physical disability (CP = 10) was prioritized. The main difference between the technique used by the university and the MIRA$^+$ method is that the university method aggregates the value of the criteria and ranks the students, whereas MIRA$^+$ first applies the multi-criteria decision-making methods and aggregates the ranks obtained by the MCDM. The advantage of using the MCDM is that it allows the criteria prioritization management policy to be applied using the criteria weighting technique. This is why MIRA$^+$ applies MCDM to prioritize the weight of the criteria and then the value of the criteria.

SAGeLogE offers the freedom to the decision-maker to choose the method to use among those installed there. Thus, based on the accommodation quota by discipline and level of study, the decision-maker has the choice of selecting the students receiving accommodation according to the WSM or TOPSIS or CoCoSo or MIRA$^+$ method. However, this choice of method must be decided at the start of each academic year. In this article we have just presented and recommended the selection by MIRA$^+$ method.

6.2. Conclusions

The SAGeLogE experimentation showed us its capacity to handle the case of accommodation allocation for the case of 2026 accommodation requests received from the University of Toamasina for the 2018-2019 academic year. These requests come from different discipline and levels of study. Two steps are applied when processing accommodation requests, including testing the basic criteria and ranking according to social criteria. The first step gave us the results that 1804 students met the basic criteria. This is how SAGeLogE begins the second stage of processing accommodation requests with the aim of ranking these 1804 students using the MIRA$^+$ method. To do this, calculating the weights of social criteria by applying the AHP method is essential. Then, SAGeLogE ranks these 1804 students using the multi-criteria decision-making methods WSM, TOPSIS and CoCoSo. We obtained different ranks according to each of these methods. So, a correlation test of these ranks was carried out applying the Kendall's rank correlation

coefficient. The result gave us coefficients of 78% to 90%, which means that the WSM, TOPSIS and CoCoSo methods have the same direction of correlation. Subsequently, the MIRA$^+$ method was applied to aggregate these different ranks to obtain a new compromise rank between these three methods. We then checked the correlation of the MIRA$^+$ ranks compared to WSM, TOPSIS and CoCoSo by the Kendall rank correlation coefficient. Respectively, the coefficient is 93%, 89% and 90%. Thus, the rank of the MIRA$^+$ method is validated.

Note that for this academic year, 1249 accommodations are available, while the number of students meeting the basic criteria is 1804. So, the accommodation quota technique by discipline and level of study was applied to share equitably these 1249 student accommodations with different discipline and levels of study at the University of Toamasina. Once the accommodation quota by discipline and level of study is calculated, SAGeLogE will select the 1249 students receiving housing according to the rank obtained by the MIRA$^+$ method. Throughout this article, we have presented the case of M2 Law students to illustrate the capacity of SAGeLogE. To facilitate the reading of this processing, SAGeLogE can extract summaries in the form of diagrams to provide a visualization of the results to decision-makers (Figure 28, Figure 29).

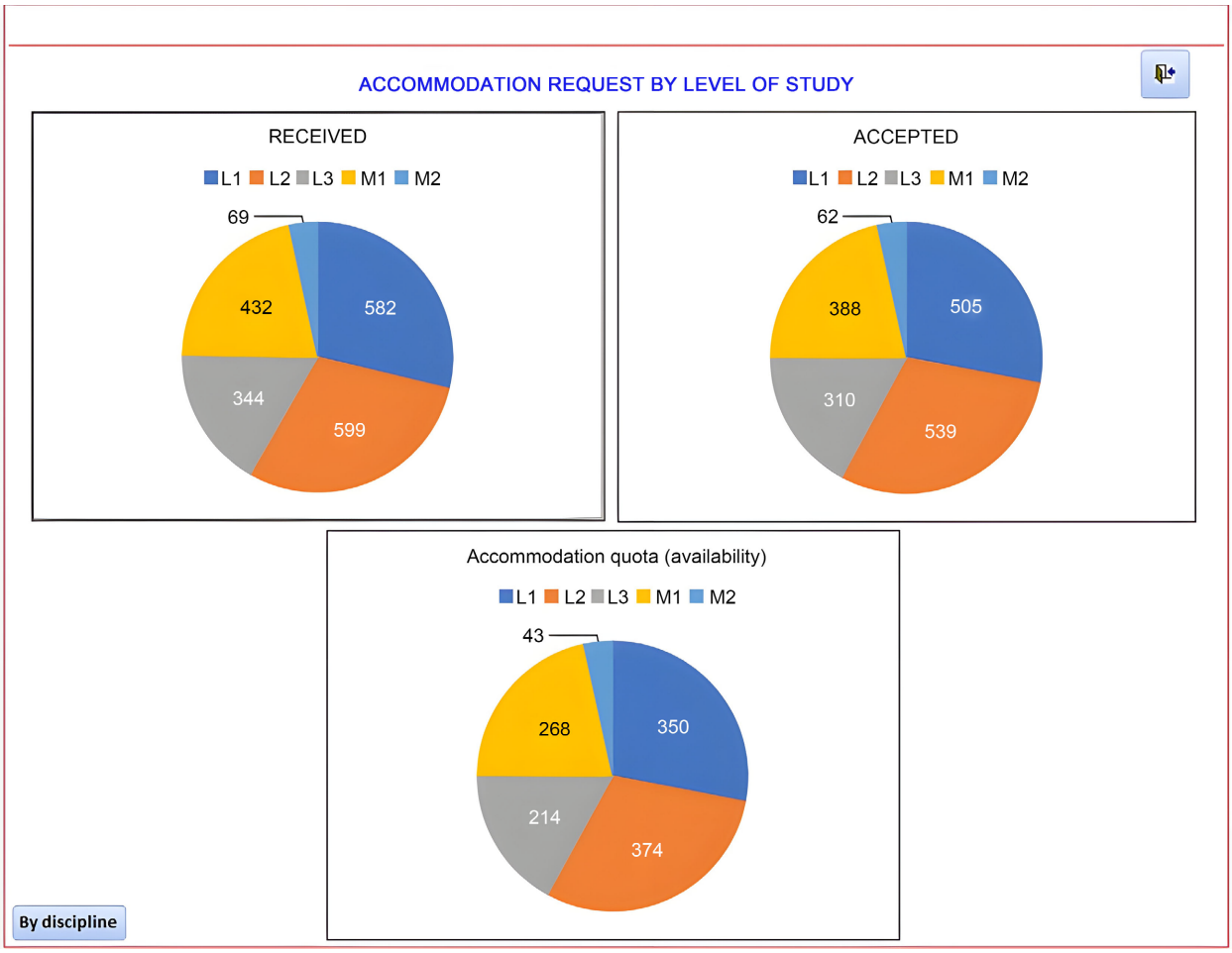

Figure 28. Summary of requests received, accepted and accommodation quota by level.

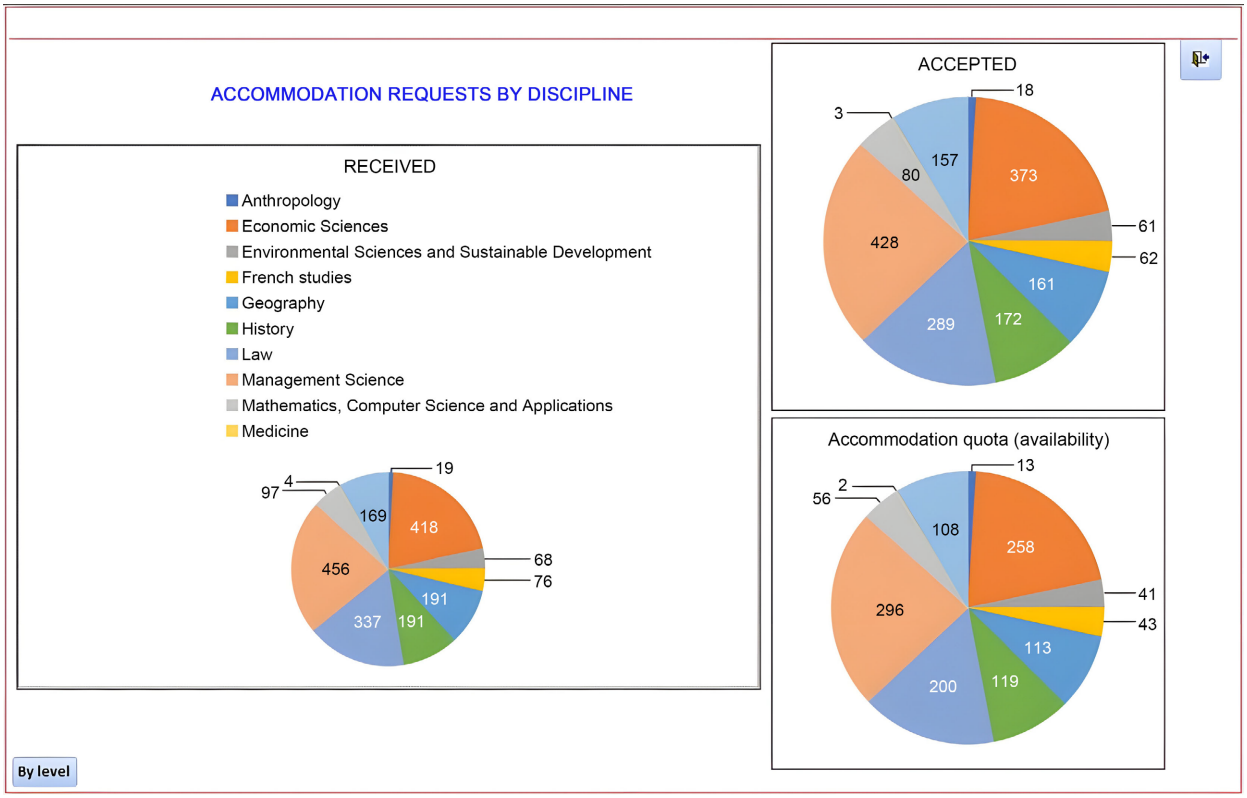

Figure 29. Summary of requests received, accepted and accommodation quota by discipline.

During this application, we noted the limit of the CoCoSo multi-criteria decision-making method. However, when one of the social criteria has the same value for all students, it is impossible to calculate the decision matrix. Also, when a student takes minimum values on all social criteria, it is impossible to obtain the assessment score k_{ib}. If one of these two cases exists, therefore the CoCoSo method can't rank the students. Thus, in the next research we will propose to correct the algorithm of the CoCoSo method.

Thus, in its future version, the newly developed method will be installed in SAGeLogE to introduce an extended version the CoCoSo method. Also, recommendation algorithms will be installed in SAGeLogE to recommend the student selection method based on the Kendall correlation coefficient.

Another prospect will be to allow decision-makers to choose the quota of student accommodation by discipline and level of study.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Massy, W.F. (1996) Resource Allocation in Higher Education. University of Michigan Press, Ann Arbor. https://doi.org/10.3998/mpub.14347

[2] Savills (2018) Market Report 2018: Australian Student Accommodation.

https://www.savills.com.au/publications-pdf/s2ht-studentaccomreport-oct18-fa-web.pdf

[3] Belghith, F., Ferry, O., Patros, T. and Tenret, E. (2021) Observation de la vie nationale étudiante: Repères 2020. https://www.ove-national.education.fr/wp-content/uploads/2021/01/brochure_reperes_2020-janvier-2022.pdf

[4] Rasoanaivo, R.G. (2023) Système d'aide à la décision multicritère pour l'allocation de logements étudiants. PhD Thesis, Université de Toulouse, Toulouse. https://hal.science/tel-04119898

[5] Brown, L. (2022) Student Accommodation: National Student Accommodation Survey 2022—Results. https://www.savethestudent.org/accommodation/national-student-accommodation-survey-2022.html

[6] Podunavac, I., Crnjac Milić, D. and Nenadić, K. (2019) Proposal for a Web Portal Managing Registration for Student Accommodation in a Dormitory. *Tehnički Glasnik*, **13**, 75-80. https://doi.org/10.31803/tg-20180629110602

[7] Calgary University (2015) Student Accommodation Policy of University of Calgary. https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Student-Accommodation-Policy.pdf

[8] Ulster University (2019) Allocation Criteria 2019/2020. https://www.ulster.ac.uk/__data/assets/pdf_file/0010/403759/allocation-criteria1920.pdf

[9] University of Chichester (2020) Accommodation Allocation Policy and Procedures. https://www.chi.ac.uk/app/uploads/2021/11/allocation-policy-version-26-2020-21_0.pdf

[10] R.H. University of London (2018) Student Accommodation Allocation Policy 2019/20. https://intranet.royalholloway.ac.uk/students/assets/docs/pdf/student-accommodation-allocation-policy-201920.pdf

[11] Rakotoarivelo, J.-B. (2018) Aide à la décision multi-critère pour la gestion des risques dans le domaine financier. These de Doctorat, Toulouse 3, Toulouse. http://www.theses.fr/2018TOU30067

[12] Nayak, V. (2018) A Survey on Multi-Criteria Decision Making Methods in Software Engineering. *International Journal of Innovative Science and Research Technology*, **3**, 366-374. https://www.academia.edu/35420903/a_survey_on_multi_criteria_decision_making_methods_and_its_applications

[13] Hadikurniawati, W., Winarno, E. and Santoso, D.B. (2019) Purwatiningtyas: A Mixed Method Using AHP-TOPSIS for Dryland Agriculture Crops Selection Problem. 2019 3*rd International Conference on Informatics and Computational Sciences* (*ICICoS*), Semarang, 29-30 October 2019, 1-5. https://doi.org/10.1109/ICICoS48119.2019.8982415

[14] Bagi, Y.S., Suyono, S. and Tomatala, M.F. (2020) Decision Support System for High Achieving Students Selection Using AHP and TOPSIS. 2020 2*nd International Conference on Cybernetics and Intelligent System* (*ICORIS*), Manado, 27-28 October 2020, 1-5. https://doi.org/10.1109/ICORIS50180.2020.9320823

[15] Rasoanaivo, R.G. (2020) la méthode promethee pour l'aide à la décision multicritère: Application à la gestion d'attribution de logements universitaires. Report, Mémoire de dea en mathématiques, informatique et applications, Université de

Toamasina, Toamasina. https://hal.science/hal-04060112

[16] Irfan, M., Elavarasan, R.M., Ahmad, M., Mohsin, M., Dagar, V. and Hao, Y. (2022) Prioritizing and Overcoming Biomass Energy Barriers: Application of AHP and G-TOPSIS Approaches. *Technological Forecasting and Social Change*, **177**, Article ID: 121524. https://doi.org/10.1016/j.techfore.2022.121524

[17] Mojaver, M., Hasanzadeh, R., Azdast, T. and Park, C.B. (2022) Comparative Study on Air Gasification of Plastic Waste and Conventional Biomass Based on Coupling of AHP/TOPSIS Multi-Criteria Decision Analysis. *Chemosphere*, **286**, Article ID: 131867. https://doi.org/10.1016/j.chemosphere.2021.131867

[18] Tscheikner-Gratl, F., Egger, P., Rauch, W. and Kleidorfer, M. (2017) Comparison of Multi-Criteria Decision Support Methods for Integrated Rehabilitation Prioritization. *Water*, **9**, Article No. 68. https://doi.org/10.3390/w9020068

[19] Chourabi, Z., Khedher, F., Dhouib, A. and Cheikhrouhou, M. (2018) Multi-Criteria Decision Making in Workforce Choice Using AHP, WSM and WPM. *The Journal of the Textile Institute*, **110**, 1092-1101. https://doi.org/10.1080/00405000.2018.1541434

[20] Fomba, S. (2018) Décision multicritère: Un système de recommandation pour le choix de l'opérateur d'agrégation. Theses, Université Toulouse 1 Capitole (UT1 Capitole), Toulouse. https://hal.archives-ouvertes.fr/tel-03726764

[21] Safrizal, Tanti, L., Thanri, Y.Y., Adhar, D. and Fahrozi, W. (2019) Decision Support System Selection of Aviation Student Departments with TOPSIS Method. 2019 7*th International Conference on Cyber and IT Service Management* (*CITSM*), Jakarta, 6-8 November 2019, 1-6. https://doi.org/10.1109/CITSM47753.2019.8965375

[22] Ulutaş, A., Popovic, G., Radanov, P., Stanujkic, D. and Karabasevic, D. (2021) A New Hybrid Fuzzy PSI-PIPRECIA-CoCoSo MCDM Based Approach to Solving the Transportation Company Selection Problem. *Technological and Economic Development of Economy*, **27**, 1227-1249. https://doi.org/10.3846/tede.2021.15058

[23] Choudhary, V. and Mishra, A. (2021) Analyzing the Critical Success Enablers of Industry 4.0 Using Hybrid Fuzzy AHP-CoCoSo Method. *Journal of Industrial Integration and Management*, **7**, 493-514. https://doi.org/10.1142/S2424862221500184

[24] Aragon, Y. (2005) Le logement étudiant à toulouse. Diagnostic. *Droit et Ville*, **59**, 207-211. https://doi.org/10.3406/drevi.2005.1879

[25] Dubet, F. and Sembel, N. (1994) Les étudiants, le campus et la ville. Le cas de bordeaux. *Annales De La Recherche Urbaine*, **62**, 225-234. https://doi.org/10.3406/aru.1994.1798

[26] Ducray, F. (2013) Gestion et place du crous dans le logement étudiant. These de Doctorat, Bordeaux 4, Bordeaux. https://www.theses.fr/2013BOR40066

[27] Grignon, C. (2000) La vie matérielle: La question du logement. PUF. https://hal.inrae.fr/hal-02837325

[28] Mayer, B. (2022) The Student Accommodation Sector around the World. HousingAnywhere. https://housinganywhere.com/student-accommodation-around-the-world

[29] Spire, Z. (2018) Student Residential Accommodation and Student Engagement: A Study of Two Cases in England.

[30] Tretiack, P. (2003) Logement étudiant: Un brin de grâce dans un monde de médiocrité.

[31] Hammad, D., Musa, J., Rishi, A. and Ayuba, I. (2013) Criteria for the Selection of Students Accommodation Model in Nigeria Tertiary Institutions Using Analytic

Hierarchy Process. *Academic Research International*, **4**, 550-556.

[32] Simpeh, F. and Shakantu, W. (2020) An On-Campus University Student Accommodation Model. *Journal of Facilities Management*, **18**, 213-229. https://doi.org/10.1108/JFM-03-2020-0017

[33] Zhendong, J. and Moore, R. (2000) Specification of Software Systems for Managing Student Accommodation and a Research Laboratory Network. UNUIIST, Macau.

[34] Scutariu, A. and Alexandrescu, A. (2015) Allocation Accommodation in a University Campus.

[35] ANU (2021) Accommodation Guarantee at ANU. https://www.anu.edu.au/study/accommodation/accommodation-application-advice/accommodation-guarantee-at-anu

[36] HKUST (2018) Hall Allocation Policy for Undergraduate Students (for Residential Year Residences). Student Housing and Residential Life, Stud. Hous. Resid. LIFE. https://shrl.hkust.edu.hk/admission-policy/ug

[37] LSBU (2020) Accommodation Allocation Policy 2020-2021. https://www.lsbu.ac.uk/__data/assets/pdf_file/0004/263146/Accommodation-Allocation-Policy.pdf

[38] Oxford Brookes (2023) University Halls Allocation Policy. Oxford Brookes University, Oxford. https://www.brookes.ac.uk/getmedia/7e658905-88ea-4fe8-b9a7-3918ea4e87d5/accommodation-allocation-policy.pdf

[39] Savills (2021) Operational Capital Markets: Australian Student Accommodation 2021. https://pdf.savills.asia/asia-pacific-research/australian-research/australia-student-accommodation/savills-student-accommodation-research-report-dec-2021.pdf

[40] Warwick (2022) Accommodation Allocation Policy 2022/2023. https://warwick.ac.uk/services/accommodation/studentaccommodation/apply/22/new/allocation_policy_22.pdf

[41] York St John University (2023) Allocation Policy for Student Accommodation. https://www.yorksj.ac.uk/media/content-assets/accommodation/documents/23.24-Allocation-Policy.pdf

[42] Rasoanaivo, R.G. and Zaraté, P. (2024) A Rank Aggregating Method Based on Several Multi-Criteria Methodologies "Minimum of Ranks": A Case Study for Student's Room Allocation. *International Journal of Decision Support Systems*, **5**, 75-101. https://doi.org/10.1504/IJDSS.2024.137246

[43] Jahan, A., Edwards, K.L. and Bahraminasab, M. (2016) 4. Multi-Criteria Decision-Making for Materials Selection. In: Jahan, A., Edwards, K.L. and Bahraminasab, M., Eds., *Multi-Criteria Decision Analysis for Supporting the Selection of Engineering Materials in Product Design*, 2nd Edition, Butterworth-Heinemann, Oxford, 63-80. https://doi.org/10.1016/B978-0-08-100536-1.00004-7

[44] Saaty, T.L. (1977) A Scaling Method for Priorities in Hierarchical Structures. *Journal of Mathematical Psychology*, **15**, 234-281. https://doi.org/10.1016/0022-2496(77)90033-5

[45] Zadeh, L. (1963) Optimality and Non-Scalar-Valued Performance Criteria. *IEEE Transactions on Automatic Control*, **8**, 59-60. https://doi.org/10.1109/TAC.1963.1105511

[46] Hwang, C.-L. and Yoon, K. (1981) Multiple Attribute Decision Making. Springer, Berlin. https://doi.org/10.1007/978-3-642-48318-9

[47] Hwang, C.-L., Lai, Y.-J. and Liu, T.-Y. (1993) A New Approach for Multiple Objective Decision Making. *Computers & Operations Research*, **20**, 889-899. https://doi.org/10.1016/0305-0548(93)90109-V

[48] Yazdani, M., Zaraté, P., Kazimieras Zavadskas, E. and Turskis, Z. (2019) A Combined Compromise Solution (CoCoSo) Method for Multi-Criteria Decision-Making Problems. *Management Decision*, **57**, 2501-2519. https://doi.org/10.1108/MD-05-2017-0458

[49] Kendall, M.G. (1938) A New Measure of Rank Correlation. *Biometrika*, **30**, 81-93. https://doi.org/10.1093/biomet/30.1-2.81

[50] Sprague, R.H. (1980) A Framework for the Development of Decision Support Systems. *MIS Quarterly*, **4**, 1-26. https://doi.org/10.2307/248957

[51] Marakas, G.M. (2003) Decision Support Systems in the 21st Century. Prentice Hall, New York.

[52] Eom, H.B. and Lee, S.M. (1990) Decision Support Systems Applications Research: A Bibliography (1971-1988). *European Journal of Operational Research*, **46**, 333-342. https://doi.org/10.1016/0377-2217(90)90008-Y

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