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► To cite this version:

Rôlin Gabriel Rasoanaivo, Joseph Alphonse Tata. A new technique of ranking Madagascar's Universities using CoCoFISo method in a multi-criteria decision support system: MadUrank. International Journal of Scientific Research in Computer Science and Engineering, 2024, 12 (4), pp.18-31. hal-04689348

HAL Id: hal-04689348

<https://hal.science/hal-04689348v1>

Submitted on 6 Sep 2024

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Research Article

A New Technique of Ranking Madagascar's Universities Using CoCoFISo Method in a Multi-Criteria Decision Support System: MadUrank

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Received: 24/Jun/2024; Accepted: 26/Jul/2024; Published: 31/Aug/2024

Abstract— The ranking of national universities provides an additional means of gauging the performance of universities that have not yet been included in global rankings. In the case of Madagascar, we proposed the implementation of a multi-criteria decision support system, designated as MadUrank, for the purpose of ranking the six public universities in the country. The system employs two distinct methodologies. Firstly, the method based on the removal effects of criteria (MEREC), is used to establish the relative importance of the criteria. Secondly, the combined compromise for ideal solution (CoCoFISo) method, is employed to determine the ranking of universities. The selection of criteria was based on the availability of data, with five criteria ultimately chosen. These were the number of students registered (STUREG), the ratio of students to administrative and technical staff (ATS), the ratio of students to permanent teachers (PTEACH), the success rate in examinations (SUCCES), and the percentage of students receiving scholarships (STUSCHO). The data set comprises observations from 2016 to 2020. In consideration of the data set, the MEREC method afforded priority to the STUREG criterion for the years 2016, 2017, and 2020, and to the STUSCHO criterion for the years 2018 and 2019. In accordance with the aforementioned priority criteria and the data set, the CoCoFISo method designated the Université d'Antananarivo as the top-ranked institution in 2016 and the Université de Fianarantsoa as the top-ranked institution from 2017 to 2020.

Keywords— Universities rankings, Madagascar's Universities, Performance criteria, MEREC, CoCoFISo, MadUrank

1. Introduction

The Ministry of Higher Education and Scientific Research in Madagascar has been in existence since 1977. During the period between 2004 and 2014, the institutes and universities in Madagascar welcomed an average of 42,143 to 106,333 students. These students were trained by an average of 1,997 permanent teachers (1,077 in 2004) and supervised by an average of 4,235 administrative and technical staff members. This represents a significant increase in the number of students and staff members compared to the figures recorded in 2004, when the institutes and universities welcomed an average of 3,780 students and employed an average of 3,780 administrative and technical staff members. In response to the globalisation and international development of higher education, the Malagasy authorities have initiated the gradual adoption of the LMD (Licence - Master - Doctorate) system since 2013. This reform aims to confer international validity upon Malagasy university diplomas and to facilitate student mobility between the different departments and courses. The LMD system is currently facilitating the reorganization of training and research in universities, enabling the design and

implementation of new courses and the adaptation, development, or transformation of existing courses with a view to scientific expansion. From 2017 to 2022, the enrolment rate in higher education is projected to fluctuate between 5.3% and 6.1%. This figure represents the total percentage of students enrolled in relation to the officially defined school-age population, which is typically considered to be the 18-22 age group. As outlined in the list compiled by the Ministry of Higher Education and Scientific Research in December 2023 [1], there are 76 public (not including Madagascar's national distance learning centre: CNTEMAD) and 184 private higher education institutions distributed across Madagascar's 22 regions. Subsequently, the public institutions are classified according to their affiliation with one of Madagascar's six public universities. The universities are situated in the provincial capitals of Madagascar, and each bears the name of the province in question. These include the Université d'Antananarivo (UV), Université d'Antsiranana (UD), Université de Fianarantsoa (UF), Université de Mahajanga (UM), Université de Toamasina (UA), Université de Toliara (UT).

So, this article presents a study of these six universities. The objective is to analyse the performance of the universities from 2016 to 2020 by applying the multi-criteria decision-making method. Multi-criteria decision-making methods are employed when confronted with a multitude of criteria and disparate measurement units, with the objective of evaluating potential alternatives. Therefore, the application of multi-criteria decision-making methods yields superior results, rather than an optimal outcome. A review of the literature reveals a plethora of multi-criteria decision-making methods, some of which are worthy of mention: the Analytic Hierarchy Process (AHP), the Best Worst Method (BWM), the Complex Proportional Assessment (COPRAS), the Combined Compromise for Ideal Solution (CoCoFISo), the Criteria Importance Through Intercriteria Correlation (CRITIC), the Multi-Attributive Border Approximation Area Comparison (MABAC), the Full Consistency Method (FUCOM), and the Step-wise Weight Assessment Ratio Analysis (SWARA), Method based on the removal effects of criteria (MERECE). These multi-criteria decision-making techniques are employed in a variety of sectors, including finance [2], agriculture [3], resource allocation [4], and physics [5], among others. Generally, these methods can be classified into two principal groups: those used to calculate the weights of the criteria and those used to evaluate the alternatives. The benefit of employing such methodologies is that they facilitate the attainment of a compromise result from a multitude of criteria.

The aforementioned rationale underpins our decision to use multi-criteria decision-making methodologies, given that the evaluation of universities inherently entails a multi-criteria approach. Consequently, we shall implement these methodologies in accordance with the data that we have collated. As this is a research project, it is our intention to provide decision-making to the various stakeholders in higher education in Madagascar. We would like to assist the person in charge at the Ministry responsible for higher education, the person in charge at the universities and, above all, the students. The Ministry of Higher Education seeks to gain insight into the evolution of universities under its technical supervision. Universities aim to ascertain their position in relation to other institutions. Students seek guidance in their academic choices.

In order to achieve this, the second section presents a concise review of the existing literature on the performance of universities in different countries. Subsequently, the third section will present the methodology employed in the research, which pertains to the algorithm utilised in the aforementioned methods. In the fourth section, we will present the details of the MadUrank system, which has been developed for this purpose. The fifth section will present the data and results, which will then be subjected to analysis and discussion. In conclusion, this study presents its findings and proposes future avenues for research.

2. Literature review

Recently, there has been a trend towards ranking the universities in a country. This is interesting because each

country has its own development situation and its own university management. Thus, the criteria for ranking universities remain specific from one country to another.

In 2017, Horn and his colleagues [6] conducted a ranking of the seventy seven research universities in the United States for the 2001-2002 academic year. The classification criteria are grouped into five categories, namely student characteristics, scholar characteristics, research orientation, curricular content, and organisational support. To obtain the weights for the criteria, a group of experts was consulted. Subsequently, the data was standardised, weighted and aggregated. The objective was to develop an overall index for ranking the establishments. The results demonstrate that Columbia University was the highest-ranked institution.

In 2018, Ivančević and Luković extracted the national rank of seven universities in Serbia based on open data from the Serbian Ministry of Education, Science and Technological Development for the academic year 2015-2016 [7]. The criteria used were divided into two groups, including basic indicators and adjusted indicators. There are ten basic indicators, namely: income from the state budget, income from the university's own activities, total number of resources in the university's libraries, number of national projects, number of incoming and outgoing student exchanges, number of teachers and researchers, number of European credit transfer and accumulation systems, number of graduates, number of enrolled doctoral students and number of academic staff. The adjusted indicators represent these ten basic indicators except for those which are divided by the number of students enrolled, the number of staff (all staff or only academic staff) or a sum of these two elements. The ranking process consisted of calculating ranks for each indicator formed, and then forming the overall rank of a university as a function of the ranks for individual indicators. The result showed that the University of Belgrade was in first place for the basic indicators and the University of Arts in Belgrade was in first place for the adjusted indicators.

In 2019, Sivakumaren and Rajkumar ranked the ten Indian universities on three criteria including publications, citations and citation rate [8]. The data relates to 2016 and was taken from Web of Science, Scopus, and the Indian Citation Index. The ranking for each university was done according to each of the criteria. So, a result, each university received three rankings for each criterion. For the publication and citation criterion, the Indian Institute of Science was ranked first. On the criterion of citation rate, the University of Delhi was ranked first.

To rank the 166 Turkish universities, Ozdagoglu and his colleagues in 2020 [9] selected the following five criteria based on the 2019 year: article scores, citation scores, scientific document scores, PhD Scores, and the number of lecturer divided by the number of student scores. Two multi-criteria decision-making methods, Combined Compromise Solution (CoCoSo) and MARCOS, were used. The result was that Hacettepe University ranked first in each of these two methods.

In order to extract the performance of Brazilian universities from 2017 to 2020, Prado in 2021 used the U-MULTIRANK system, a multidimensional academic ranking created in Europe, with results since 2014 [10]. This system uses five dimensions to evaluate universities, including teaching and learning, research, knowledge transfer, international orientation, and regional engagement. Each dimension is made up of indicators. In relation to these indicators, the author pointed out that some data were missing from Brazilian universities, but he had to rank the universities according to the existing data. The results are as follows: from 2017 to 2019, São Paulo State University was ranked first, compared to the Escola Superior de Propaganda e Marketing in 2020.

In order to rank ten anonymous Moroccan universities, Nayme and his colleagues [11] in 2023 had identified sixty-nine criteria, which they divided into four areas according to the Moroccan framework for the evaluation and quality assurance of national higher education institutions. The aforementioned areas were assigned the following weights: The weightings were as follows: 30% for training, 30% for research, cooperation and partnership, 20% for services rendered to society and a final percentage of 20% for student life. In order to obtain the final score, the value of each criterion was first multiplied by the corresponding weighting factor, and the resulting values were then added together. This approach was employed to ensure that the ranking of universities was not affected by differences in size. However, it should be noted that disparities may exist between the different universities. Consequently, the ranking was presented by university group instead of by university.

In order to analyse the impact of the criteria weights on the university rankings, this 2024 Do [12] selected the case of the top ten Universities in Vietnam. The six criteria employed in the Vietnam University Rankings, the inaugural and currently the sole ranking system in Vietnam, were retained. The criteria are as follows: recognition of quality; teaching; scientific publications; contributions to science, technology, and invention; student quality; and facilities. Four methods were employed for calculating the weights of the criteria: the equal weight method, the weights determined by the Vietnam University Rankings system, Entropy and logarithmic percentage change-driven objective weighting (LOPCOW). Furthermore, he employed four distinct methodologies for the purpose of ranking the universities: Proximity Indexed Value (PIV), Ranking of Alternatives with Weights of Criterion (RAWEC), Root Assessment Method (RAM), and Simple Ranking Process (SRP). The results demonstrated that despite the varying weights assigned to the criteria in each university ranking method, the resulting ranks remained largely consistent. Furthermore, even when the rankings produced by the Vietnam University Rankings system were considered, the four leading universities were able to maintain their positions throughout the course of the experiment. The four top-ranked universities are Vietnam National University, Vietnam National University Ho Chi Minh City, Ton Duc Thang University and Hanoi University of Science and Technology.

In comparison to the preceding cases, the MadUrank initiative has been proposed for Madagascar with the objective of determining the annual performance of universities. The subsequent section will present the ranking methodology that will be applied.

3. Methodological approach

Multi-criteria methods are well suited to solving the ranking problem [13]. They are generally applied in two stages: calculating the weight of the criteria and ranking the alternatives. For each of these stages, there are several methods to be implemented in the literature [14], [15], [16], but the choice depends on the specificity of the case to be treated. Thus, for our case, we have chosen the method based on the removal effects of criteria (MEREC) [17] as it is an objective method that does not require the intervention of the decision-maker, but as long as the data is available, the criteria may be ordered according to the results of the algorithm. Secondly, the combined compromise for ideal solution (CoCoFISo) [18] method was chosen to rank the universities as it is the most recent multi-criteria method, and its experimentation in various fields is to be recommended.

In all cases, the data will be presented in the form of a matrix called performance matrix.

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}; i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (1)$$

In this context, m represents the number of alternatives, which are the universities in question and n represents the university performance criteria, which will be defined in due course.

We will then discuss the algorithm of these two methods.

3.1. MEREC method

The MEREC approach is predicated on the elimination of certain criteria. Once the performance matrix has been standardised, a measure of the performance of the alternatives is defined using a simple logarithmic measure with equal weightings. To evaluate the impact of removing each criterion, the absolute deviation method was employed. This measure reflects the discrepancy between the overall performance of the alternative and its performance when a criterion is removed.

The algorithm is comprised of four distinct steps [17] :

- *Normalisation of matrix*

$$r_{ij} = \frac{j^{\min x_{ij}}}{x_{ij}} \text{ for benefit criteria} \quad (2)$$

$$r_{ij} = \frac{x_{ij}}{j^{\max x_{ij}}} \text{ for cost criteria} \quad (3)$$

- *Performance values*

$$S_i = \ln \left(1 + \frac{\sum_{j=1}^n |\ln(r_{ij})|}{n} \right) \quad (4)$$

$$S'_{ij} = \ln \left(1 + \frac{\sum_{j=1, j \neq k}^n |\ln(r_{ij})|}{n} \right) \quad (5)$$

- **Absolute differences of values**

$$E_j = \sum_{i=1}^m |S'_{ij} - S_i| \quad (6)$$

- **Weight of criteria**

$$w_j = \frac{E_j}{\sum_{j=1}^n E_j} \quad (7)$$

3.2. CoCoFISo method

The CoCoFISo method, which was recently created in 2024, is based on the principle of combining compromises to obtain an ideal solution. The first step is to identify the alternative comparability sequence, which is based on the weights of the criteria according to the weighted sum and weighted product model. Subsequently, the different aggregation strategies must be extracted to implement the sequence of comparability alternatives in different forms, with the aim of obtaining their final rank by the sum of the aggregations. There are four stages to the algorithm [18] :

- **Matrix normalization**

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m (x_{ij})^2}} \quad (8)$$

- **Weighted comparability sequence**

$$S_i = \sum_{j=1}^n (w_j r_{ij}) \quad (9)$$

$$P_i = \sum_{j=1}^n (r_{ij})^{w_j} \quad (10)$$

- **Aggregation strategies**

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^m (P_i + S_i)} \quad (11)$$

$$k_{ib} = \left(\frac{S_i + P_i}{1 + \frac{S_i}{1 + S_i} + \frac{P_i}{1 + P_i}} \right) \quad (12)$$

$$k_{ic} = \frac{\lambda(S_i) + (1-\lambda)(P_i)}{(\lambda \max_i S_i + (1-\lambda) \max_i P_i)}; 0 \leq \lambda \leq 1 \quad (13)$$

- **Final ranking**

$$k_i = (k_{ia} k_{ib} k_{ic})^{\frac{1}{3}} + \frac{1}{3} (k_{ia} + k_{ib} + k_{ic}) \quad (14)$$

4. MadUrank development

MadUrank is an acronym for "Madagascar's Universities ranking". This is the designation we have assigned to our software, which has been developed with the objective of ranking Madagascar's universities. It is a multi-criteria decision support system that implements the MEREC and CoCoFISo methods. The following section presents an overview of the software's development.

4.1. From diagrams to database

In terms of its architectural composition, the multi-criteria decision support system is constituted by six fundamental elements: the database management system (DBMS), the model base management system (MBMS), the knowledge engine (KE), the multi-criteria decision-making method management system (MCDMMS), the user interface and the users themselves [19] presented in the **Figure 1** below.

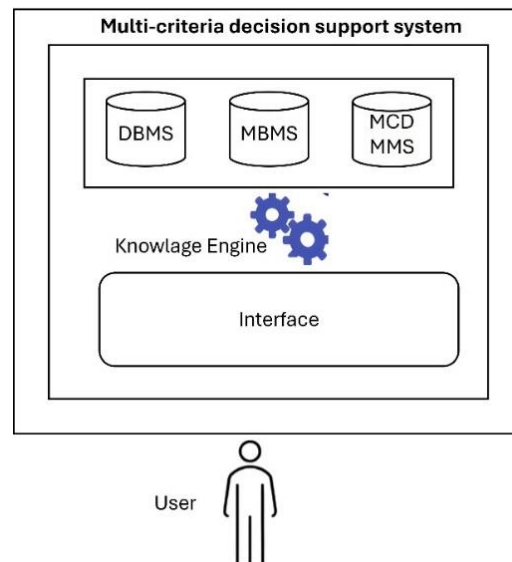


Figure 1. MadUrank architecture

The class diagram is made up of five classes linked by two sets of relationships. The first set is made up of the UNIVERSITY class, which stores the different universities in the country, the ACADEMIC YEAR class, which stores the academic years, and the CRITERIA class, which stores the criteria. The second group of classes is made up of two classes: the USER class, which stores the identity of the user, and the GROUPE USER class, which qualifies the user group.

The **Figure 2** below shows the construction of this diagram.

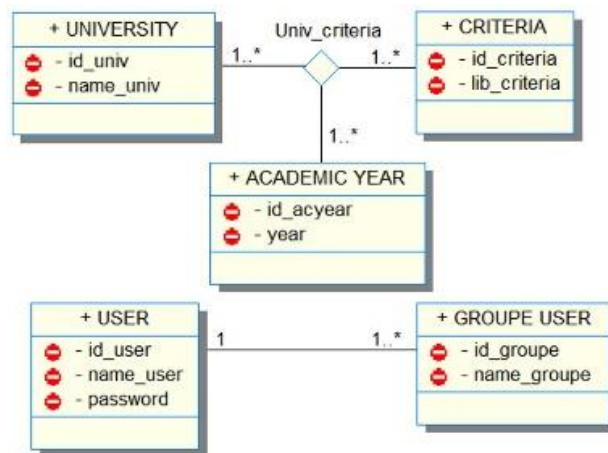


Figure 2. MadUrank class diagram

Once the logical model and scripts have been generated, the database is made up of six tables to build the database, as shown in the **Figure 3** below.

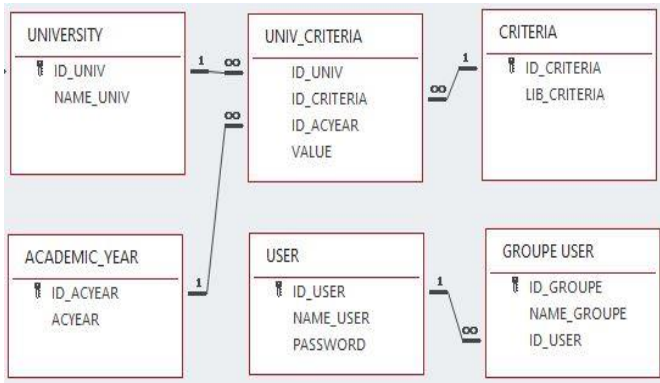


Figure 3. MadUrank table

4.2. Navigating in MadUrank

The main menu provides access to data entry and data or results display. The recommended order of data entry is: academic year, university, criteria and performance matrix. However, experienced users will be able to import data directly into the tables. Once the data is available, it can be viewed to extract the results. **Figure 4** below shows the main menu screen.

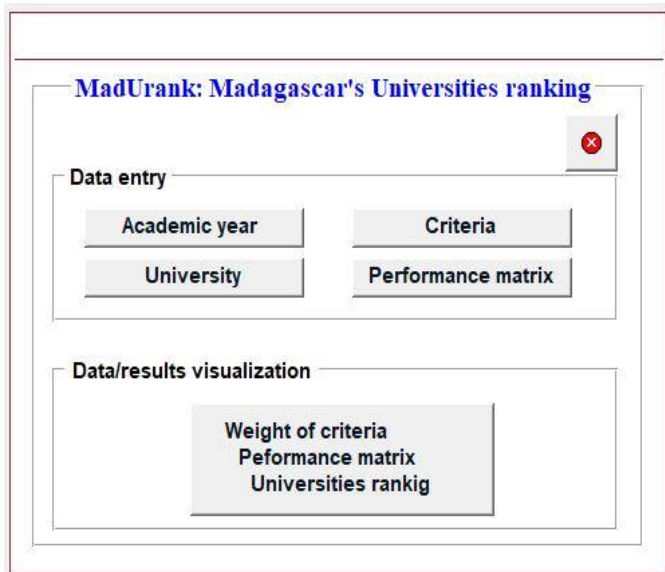


Figure 4. MadUrank main menu

The screens used to enter the data are shown in the following **Figures 5 to Figure 8**.

To view the academic year screen, select the Academic Year button from the main menu. This will display the screen shown in **Figure 5**. The academic year identification is defined as a number that increments with each additional new academic year. Only the year itself requires input.

It should be noted that the academic year constitutes the initial data entry into MadUrank upon initial utilisation.

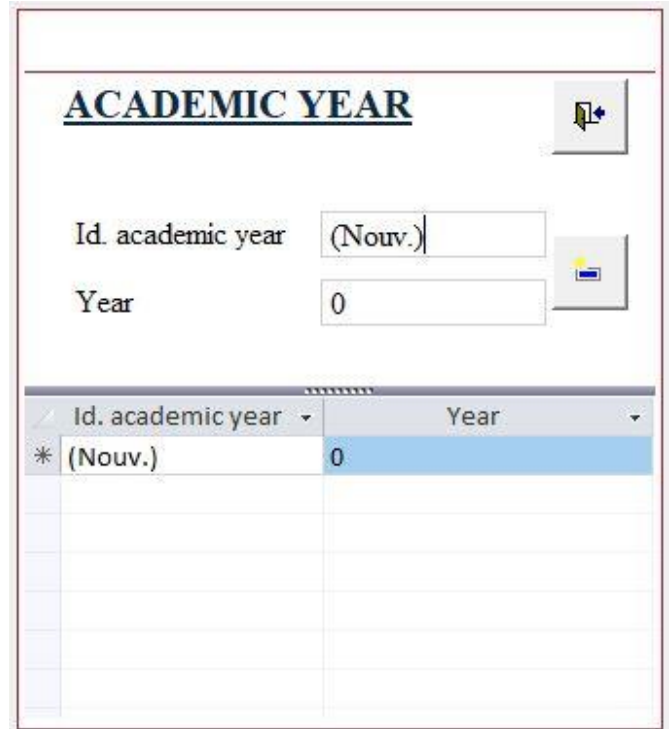


Figure 5. Academic year data entry form

The second data set to be entered into MadUrank pertains to universities. To do so, select the University button in the main menu, which will display **Figure 6**. Enter the university identification, which is an alphanumeric character, and the university name.

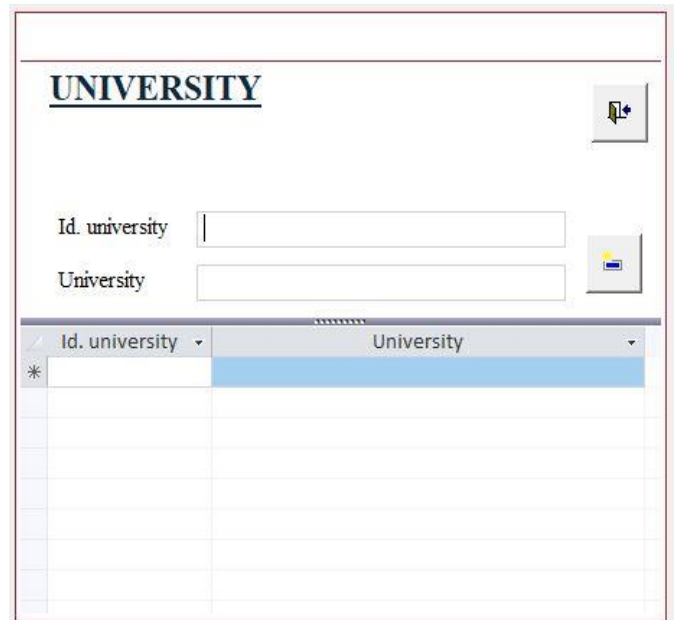


Figure 6. University data entry form

We shall now proceed to the third item of data to be input into the MadUrank system. This is the criteria by which the university will be evaluated. At this juncture, the user should click on the "Criteria" button in the main menu in order to access the screen depicted in **Figure 7**. In this section, the universities are entered individually, commencing with their identification and proceeding to their name.

CRITERIA

Id. criteria

Criteria

Id. criteria	Criteria
*	

Figure 7. Criteria data entry form

Once the academic year, university and criteria are available in MadUrank, the final data entry is completed. These are the values for each criterion for each university, which are the subject of the university evaluation. This is the performance matrix, which can be accessed by clicking on the Performance matrix button in the main menu, as shown in Figure 8 below.

To complete the value of the performance matrix, it is first necessary to select the academic year. In this section, the user is required to select the existing year from the provided drop-down list. This is the year that was initially entered by the user at the commencement of the data entry process (in Figure 5). The subsequent step is to select a university in the same manner. At this point, the user may enter the value of the criteria for the university in question. To enter the criteria values for another university, the user should simply navigate to the relevant university and enter the required values. It should be noted that in this illustration of the performance matrix (Figure 8), the criteria are indicated by C1, C2, C3, C4 and C5. However, once the user has entered the criteria (in Figure 7), these will be visible instead of C1, C2, C3, C4 and C5.

Performance matrix

Choose year

Year

University	C1	C2	C3	C4	C5
*					

Figure 8. Performance matrix data entry form

Once the data pertaining to the academic year, the universities, the criteria and the performance matrix have been made available, the initial result may be viewed. This displays the weights of the criteria calculated by the MEREC method in accordance with the performance matrix. To access this screen, click on the "Data/results visualisation" button located within the main menu. Once the screen has been displayed, the user may select a year in order to view the criteria weights according to the performance matrix. Figure 9 below shows this screen.

Data/results visualization

Choose year

Year

Weight of criteria calculated by the MEREC method

C1 C2 C3 C4 C5

Performance matrix

University	C1	C2	C3	C4	C5

Main menu University rank

Figure 9. Weighting of criteria by the MEREC method

Subsequently, by selecting the "University Rank" button in Figure 9, the user will be redirected to a screen displaying the university ranks by CoCoFISo method illustrated in Figure 10. Since no data has been entered, the universities are not yet included in the list.

CoCoFISo ranking of universities

Year

University	C1	C2	C3	C4	C5
*					

Figure 10. Ranks of universities by CoCoFISo

The results will be presented in the subsequent section, following the examination of the MadUrank. We will now proceed to analyse the results of the MadUrank experiment.

5. Data and result

We first present the data that we used for the MadUrank experiment and then we will see the results obtained once the data are inserted into the database.

5.1. Data

There are two types of data. First, the selection of universities in Madagascar that play the role of alternatives, and then the performance criteria used to evaluate these universities.

- Universities

The data we have processed covers Madagascar's six public universities (MPU) which is in the Provincial, including the Université d'Antananarivo (UV), Université d'Antsiranana (UD), Université de Fianarantsoa (UF), Université de Mahajanga (UM), Université de Toamasina (UA) and Université de Toliara (UT). The six universities selected for this study are representative of Madagascar's main academic institutions. It may be reasonably inferred that the country's other public higher education institutions have their origins in these six universities. To get the evolution of the rankings, we have chosen the five-year periods from 2016 to 2020.

- Criteria

The performance criteria were extracted from the data published on the website of the "Institut National de le Statistique de Madagascar (INSTAT)" [1], [20], [21]. It should be noted that the data published on this website are raw data. To make them easier to interpret and more relevant to our study, we have processed them to extract ratios and percentages. Thus, we have the following criteria: students registered (STUREG), the ratio of students to administrative and technical staff (ATS), the ratio of students to permanent teachers (PTEACH), the success rate in exams (SUCCES) and the percentage of students receiving scholarships (STUSCHO).

- **STUREG**: these are the numbers of registered students of all nationalities at the universities.
- **ATS**: this represents the ratio of students to administrative and technical staff. To obtain this ratio, it is necessary to divide the number of registered students by the number of administrative and technical staff (NATS).

$$ATS = \frac{STUREG}{NATS} \quad (15)$$

This ratio provides an indication of the number of students who are supported by administrative and technical staff.

- **PTEACH**: this is a ratio of students to permanent teacher. It is calculated by dividing the number of registered

students by the number of permanent teacher (NPTEACH).

$$PTEACH = \frac{STUREG}{NPTEACH} \quad (16)$$

The ratio thus obtained represents the number of students under the supervision of a single teacher.

- **SUCCES**: the following represents the examination success rate for students. The data has already been calculated and is now available for use.
- **STUSCHO**: it represents the proportion of students who have been awarded scholarships. The calculation is performed by dividing the number of students who are recipients of scholarships (NSTUSCHO) by the number of registered students, and then multiplying the resulting quotient by 100.

$$STUSCHO = \frac{NSTUSCHO}{STUREG} \times 100 \quad (17)$$

These criteria were chosen because, firstly, it is often said in Madagascar that students, teachers, and administrative staff are the three pillars of a university. Secondly, scholarships are part of the university's financial and social activities that help students in their daily lives. Finally, exam success is one of the objectives of a university and this rate helps students to choose their university. The **Table 1** below shows the annual performance matrix.

The data set comprises the values of each criterion for each university on an annual basis. To illustrate, consider the value of **31** for the UA row (second row) and the ATS column (third column) in the **Table 1**. This value represents the ratio of students to administrative and technical staff at the Université de Toamasina in 2016. This indicates that one administrative and technical staff member at the Université de Toamasina was responsible for 31 students in 2016. This value was obtained by applying formula (15) to the raw data. To obtain it, we divided the number of students registered (STUREG) by the number of administrative and technical staff (NATS) at the Université de Toamasina. It should be noted that the raw data will no longer be presented here; only the processed data is presented.

In order to manage the presentation of the **Table 1**, we will take into account the notation of the criteria from C1 to C5 as follows:

- **C1**: ATS
- **C2**: SUCCES
- **C3**: STUREG
- **C4**: PTEACH
- **C5**: STUSCHO

Table 1 : Annual performance matrix

MPU	Year	C1	C2	C3	C4	C5
UA	2016	31	61,90	8 668	89	71,69
UF		26	60,20	10 670	75	74,89
UT		17	54,50	6 634	39	72,16
UM		13	74,00	6 260	43	68,35
UV		19	52,60	32 795	40	83,77
UD		17	73,80	4 797	38	88,99
MPU	Year	C1	C2	C3	C4	C5
UA	2017	28	62,30	8 415	84	76,96
UF		38	56,30	17 383	115	62,73
UT		19	67,40	7 246	40	75,30
UM		15	71,00	7 238	44	70,50
UV		20	56,80	34 845	38	83,55
UD		20	68,60	5 640	42	94,89
MPU	Year	C1	C2	C3	C4	C5
UA	2018	15	65,60	7 872	76	70,80
UF		45	52,80	19 854	128	65,26
UT		19	62,20	7 714	41	74,76
UM		13	78,20	7 650	43	81,45
UV		20	59,40	34 221	37	83,32
UD		21	70,80	6 073	42	98,01
MPU	Year	C1	C2	C3	C4	C5
UA	2019	14	64,00	8 405	106	73,34
UF		47	73,30	21 603	139	65,65
UT		21	62,70	8 567	42	85,61
UM		14	65,10	8 216	44	79,49
UV		24	61,80	37 406	42	90,24
UD		25	70,80	7 282	51	100,00
MPU	Year	C1	C2	C3	C4	C5
UA	2020	23	73,30	10 561	149	93,62
UF		48	70,40	22 707	151	89,45
UT		18	62,80	9 146	44	81,72
UM		19	67,30	11 359	71	82,37
UV		25	63,80	37 914	44	77,83
UD		33	74,80	8 675	67	93,98

Once this data has been entered in the order recommended above, it can be viewed along with the results obtained using the MadUrank.

5.2. Results

We will present the results obtained using the methods implemented in the MadUrank. First, the weighting of the criteria calculated by the MEREC method and then the ranking of the universities according to the CoCoFISO method. The results will therefore be subjected to analysis and discussion.

- Weighting of the criteria calculated by the MEREC

The presentation will be annual depending on the data. The MEREC method has given the weights of the criteria, which we can show the details of the data and the weights of the corresponding criteria in the Figures 11 to 15 below according to the data in the database and, we have summarised in the Table 2 below the weights obtained. Subsequent to the formulation of the MEREC algorithm in MadUrank, the system generates the weight of the criteria in accordance with the data entered on an annual basis in the performance matrix table (see Figure 8).

Figure 11 below illustrates the outcome of the criterion weighting for the year 2016, as determined by the MEREC method. The advantage of this screen is that it displays not only the assigned weights for each criterion, but also the performance matrix. The aforementioned performance matrix represents the data from 2016 that was used by MEREC to calculate the criteria weights. The result of the 2016 criterion hierarchisation is a ranking of the criteria from most to least important, as follows: STUREG > ATS > PTEACH > STUSCHO > SUCCES, with respective weights of 0.26, 0.22, 0.20, 0.17 and 0.15.

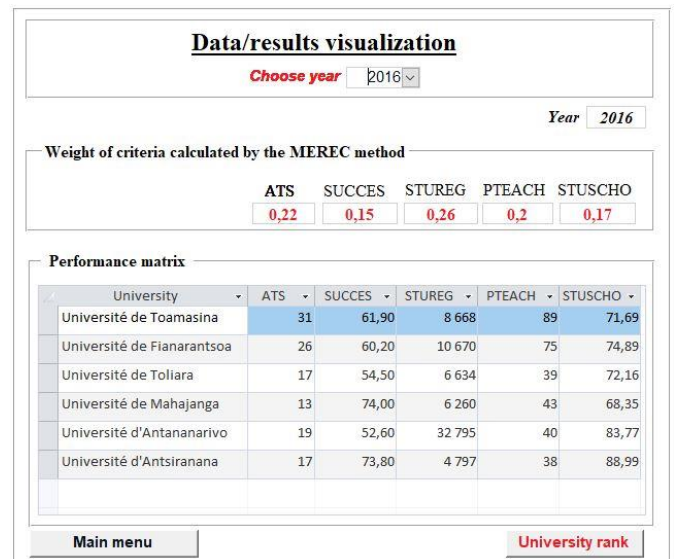


Figure 11. MEREC's weighting of criteria in 2016

In light of the fact that the criteria are evaluated on an annual basis in accordance with the performance matrix, we shall now proceed to examine the criteria for the year 2017.

The weights of the criteria obtained by the MEREC method in 2017 are presented in Figure 12 below. These are based on the performance matrix located immediately below the weights. It is evident that in the 2017 assessment, MEREC has progressively accorded greater importance to the criteria in accordance with the following logical sequence: STUREG > STUSCO > ATS = PTEACH > SUCCES. Consequently, the respective criteria have been assigned weights of 0.23, 0.21, 0.19, 0.19, and 0.18.

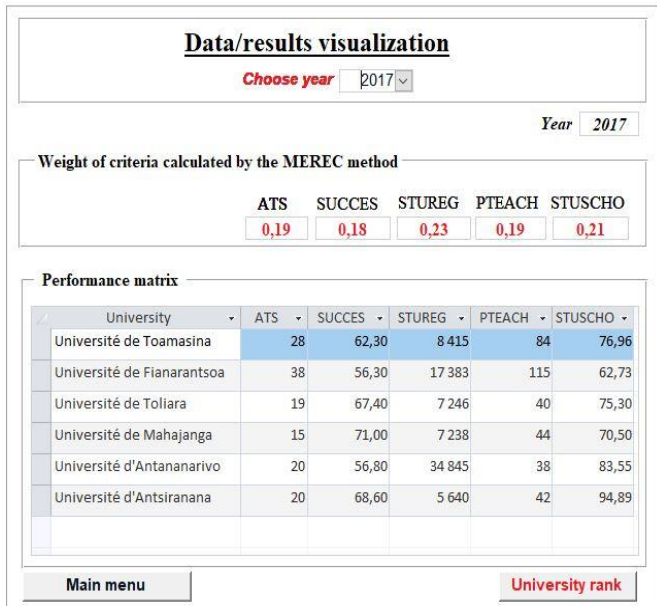


Figure 12. MEREC's weighting of criteria in 2017

In accordance with the performance matrix, MEREC provided us with the evaluations of the criteria presented in **Figure 13** below for the year 2018. The classification of the criteria according to their importance for the year 2018 was as follows: STUSCHO > PTEACH > SUCCES > ATS > STUREG. The respective weights of these criteria are 0.23, 0.21, 0.20, 0.19 and 0.17.

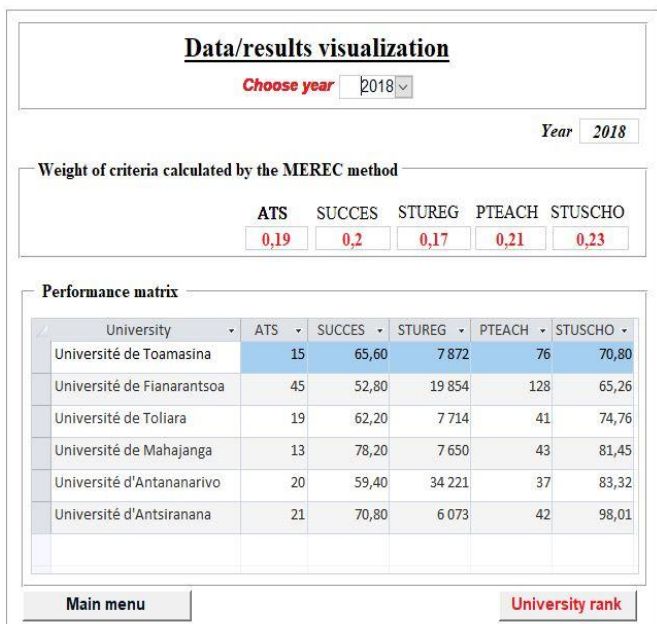


Figure 13. MEREC's weighting of criteria in 2018

With regard to the year 2019, MEREC allocated the criteria set forth in **Figure 14** below, continuing to base this allocation on the performance matrix from that same year. The criteria were assigned in accordance with their relative importance for the year 2019 was as follows: STUSCHO > PTEACH = SUCCES > ATS > STUREG. The weight assigned to each criterion ranged from 0.16 to 0.24, with the receptive weight of these criteria as 0.24, 0.21, 0.21, 0.19 and 0.16.

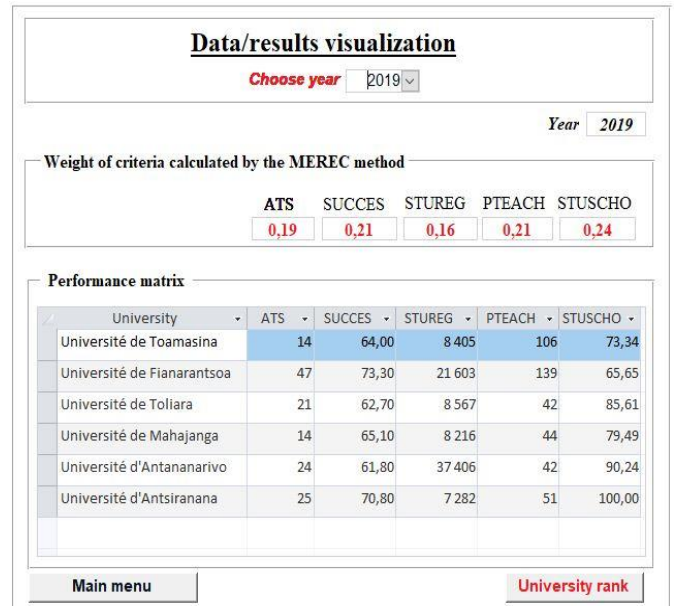


Figure 14. MEREC's weighting of criteria in 2019

The present study concludes with the year 2020. As in all previous years, MEREC presented the results of the prioritisation of the criteria for the year 2020, as illustrated in **Figure 15**. In the present case, the most significant criteria are as follows: PTEACH = STUREG > ATS > STUSCHO > SUCCES, with masses of 0.18 to 0.22. The weights of the criteria are therefore 0.22, 0.22, 0.20, 0.19 and 0.18, respectively.

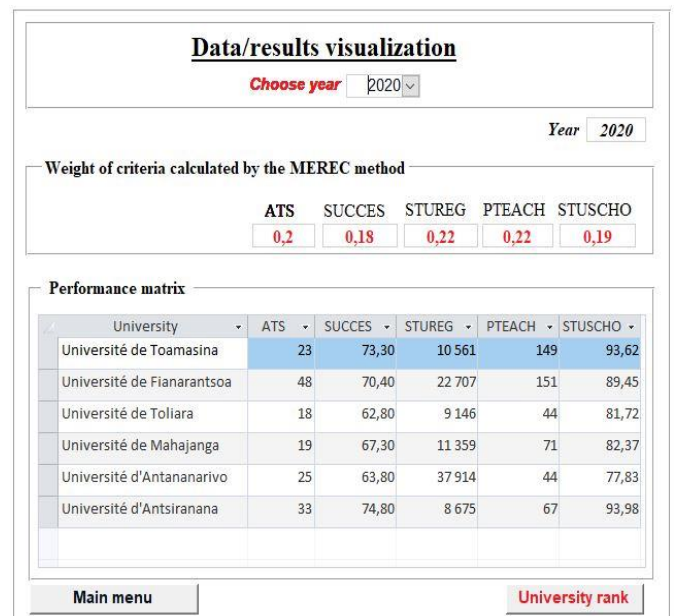


Figure 15. MEREC's weighting of criteria in 2020

In this manner, we can synthesise the significance of the criteria that are established on an annual basis. The following **Table 2** presents the weighting criteria as defined by MEREC method between 2016 and 2020.

Table 2 : Criteria weighting by MEREC from 2016 to 2020

Year	ATS	SUCCES	STUREG	PTEACH	STUSCHO
2016	0,22	0,15	0,26	0,20	0,17
2017	0,19	0,18	0,23	0,19	0,21
2018	0,19	0,20	0,17	0,21	0,23
2019	0,19	0,21	0,16	0,21	0,24
2020	0,20	0,18	0,22	0,22	0,19

The aim of this result is to determine the importance of one criterion in relation to other criteria. In other words, it is interesting to know the priority of each criterion.

So, each year, the MEREC method provides us with this situation, as we can see. For three years (2016, 2017, 2020), MEREC has calculated that the STUREG criterion is the most important, except in 2020, when it has the same priority as the PTEACH criterion. For the other two years (2018, 2019), the STUSCHO criterion was given priority.

We have also noticed that for the years with the same more important criteria, the criteria considered less important remain the same. As in 2016, 2017 and 2020, the least important criterion is SUCCESS. In 2018 and 2019, the least important criterion is STUREG.

This hierarchy of criteria has been calculated by MEREC based on the annual performance matrix.

In light of the availability of the criteria weights, the ranking of the universities will now be conducted using the CoCoFISo method.

Ranking of universities by CoCoFISo method

In MadURank, according to the data and the weights of the criteria, this ranking is done annually. The **Figures 16 to 20** below show the annual ranking of universities according to the CoCoFISo method.

Figure 16 below illustrates the university rankings according to the CoCoFISo method in 2016. The universities are ordered from first to last as follows: Université d’Antananarivo, Université de Toamasina, Université de Fianarantsoa, Université de Toliara, Université d’Antsiranana et Université de Mahajanga.

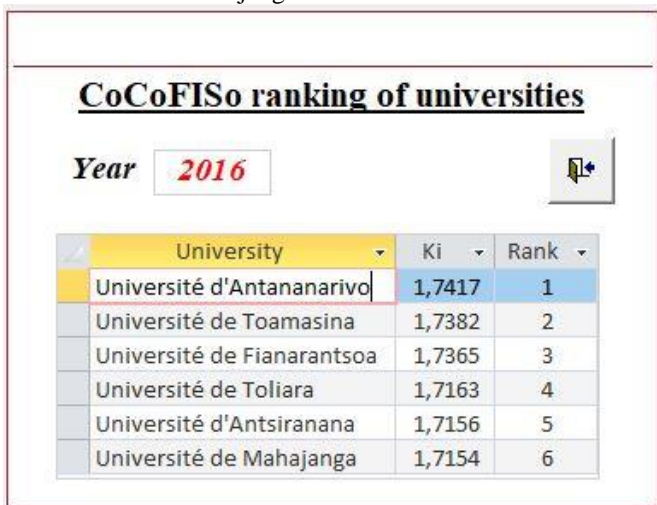


Figure 16. CoCoFISo university ranking 2016

Figure 17 below presents the university rankings for the year 2017, as determined by the CoCoFISo method. It is observed that Université de Fianarantsoa has experienced a change in rank, having previously been placed third in the previous year, but this year (2017), it has reached the first rank. The university rankings, from first to last place, are as follows: Université de Fianarantsoa, Université d’Antananarivo, Université de Toamasina, Université de Toliara, Université d’Antsiranana and Université de Mahajanga.



Figure 17. CoCoFISo university ranking 2017

The third year of results is 2018. The university rankings obtained by the CoCoFISo method are presented in **Figure 18** below. The order of the top three universities remains consistent with that of the previous year. Conversely, Université d’Antsiranana has advanced from fifth place in the preceding year to fourth place in the current year (2018). Consequently, the universities are ranked in order of merit from first to last: Université de Fianarantsoa, Université d’Antananarivo, Université de Toamasina, Université d’Antsiranana, Université de Toliara and Université de Mahajanga.



Figure 18. CoCoFISo university ranking 2018

As illustrated in **Figure 19** below, the university ranking for the year 2019 is presented. It was observed that this position

is similar to that of 2018. It is important to note that the data presented in the performance matrix, as well as the evaluations of the criteria, have undergone an evolution. However, the universities have maintained a stable ranking from 2018 to 2019 according to the CoCoFISo method. Thus, the university ranks are as follows in order of merit: Université de Fianarantsoa, Université d'Antananarivo, Université de Toamasina, Université d'Antsiranana, Université de Toliara and Université de Mahajanga.



Figure 19. CoCoFISo university ranking 2019

The 2020 period marks the conclusion of our study. Figure 20 illustrates the ranking of universities for the current year. It can be observed that the top four universities exhibited a similar ranking to that of the previous year. However, Université de Mahajanga demonstrated an upward trajectory, advancing from sixth place in the previous year to fifth place in 2020. The universities are ranked in descending order, with Université de Fianarantsoa, Université d'Antananarivo, Université de Toamasina, Université d'Antsiranana, Université de Mahajanga and Université de Toliara occupying the first, second, third, fourth, fifth and sixth positions, respectively.



Figure 20. CoCoFISo university ranking 2020

In terms of the annual rankings of universities, Figure 21 below shows how the rankings of these universities will change from 2016 to 2020.



Figure 21. Rank changes from 2016 to 2020

These situations allow us to see how the rankings of Madagascar's public universities have evolved. The CoCoFISo method was able to rank these universities according to the data we chose. This is a new way of ranking, and we could say that it is a new ranking of universities using a multi-criteria decision-making method.

According to these rankings, we have two situations: there are universities whose ranks tend to fall and there are those whose ranks tend to rise.

In the first case, we can mention:

- Université d'Antananarivo (UV), which was in first place at the beginning of the period (2016) and in second place from 2017;
- Université de Toamasina, which was ranked second at the beginning of the period (2016) and third from 2017 onwards;
- Université de Toliara, which was ranked fourth in the first two years, fifth in the following two years and sixth in 2020.

On the other hand, the universities whose rankings have changed are:

- Université de Fianarantsoa (UF), which was ranked third at the beginning of the period and first since 2017;
- Université d'Antsiranana (UD), ranked fifth in the first two years, moved up to fourth since 2018;
- Université de Mahajanga (UM), ranked last for four years, moved up to fifth place in 2020.

How did the CoCoFISo method rank these universities in this way? A detailed examination of the findings is presented below.

- **Analysis and discussion of the result**

First, let's look at the variation in the importance of the criteria. This is shown in the **Figure 22** below.



Figure 22. MEREC annual weight variation

The **Figure 22** illustrates the weighting hierarchy for each year, with the most important criteria indicated at the top and the least important at the bottom.

In terms of the relative importance of the criteria, the fundamental premise of the MEREC approach is that the most significant criterion, in terms of its impact on the performance of the alternatives, is accorded the greatest weight.

The weights assigned to the criteria vary from year to year, contingent upon the data available for analysis. The weight assigned to each criterion has a significant impact on the final ranking of universities. Indeed, the weight attributed to each criterion is a pivotal factor in the ranking of universities.

Given this weighting of the criteria, the university rankings were obtained by applying the CoCoFISo method. The basis of this method is to give a compromise ranking resulting from the accumulation of some multi-criteria methods, as we can see from its algorithm, to obtain an ideal solution. The university rankings obtained vary from year to year according to the performance matrix and the weighting of the criteria.

It should be noted that the criteria we have chosen reflect the educational resources (STUREG, PTEACH), the administrative resources (ATS), the academic work (STUSCHO) of these six universities in Madagascar in order to measure the success rate of the students in the examinations (SUCCES). If a university has significant values on the ATS and PTEACH criteria, it means that this university has fewer administrative staff and permanent teachers. And in relation to this situation, if the success rate of students in exams (SUCCES) remains high, it will be

ranked first. For this reason, CoCoFISo has ranked these universities according to the summary **Table 3** below.

Table 3 : Universities rankings by CoCoFISo 2016-2020

University	2016	2017	2018	2019	2020
Université d'Antananarivo	1	2	2	2	2
Université de Toamasina	2	3	3	3	3
Université de Fianarantsoa	3	1	1	1	1
Université de Toliara	4	4	5	5	6
Université d'Antsiranana	5	5	4	4	4
Université de Mahajanga	6	6	6	6	5

If we take the case of the Université d'Antananarivo, which came first in 2016, it is possible to interpret this ranking according to the weighting of the criteria and the performance matrix. For the first time in 2016, the hierarchy of the criteria, from the most important to the least important, is as follows: STUREG, ATS, PTEACH, STUSCHO, SUCCES. For the Université d'Antananarivo in 2016, we found according to the performance matrix that it has:

- the largest number of students compared to other universities (STUREG = 32,795);
- the interesting student-administrator ratio compared to other universities (ATS = 19; one administrator supports 19 students);
- an acceptable ratio of permanent teaching staff to students compared with other universities (PTEACH = 40; one teacher to 40 students);
- a high rate of scholarship students (STUSCHO = 83.77%);
- a student examination pass rate (SUCCES) of 52.60%.

The Université d'Antananarivo came out on top on all these criteria. So, any rank could be interpreted as such a case.

Since the MadUrank we developed was able to provide us with all these results, we can say that its experiment on five years of data for the six public universities of Madagascar was successful.

6. Conclusion and Future Scope

It is crucial to reiterate that the aim of this study is to illustrate the advantages of an alternative methodology for the structuring of academic institutions. The use of multi-criteria decision-making methods is currently being employed in a number of fields. For this reason, we have elected to utilise one of these methods for the purpose of ranking the six public universities of Madagascar.

It is established that the multi-criteria decision-making process entails the utilisation of a methodology for the determination of the relative importance of the criteria and a technique for the evaluation of the alternatives. In this case study, the MEREC and CoCoFISo methods were employed. The experimental data span the five-year period from 2016 to 2020, with the objective of determining the evolution of the rank of the six public universities in Madagascar. To facilitate the reuse of the database, the MadUrank was designed to facilitate the processing of the data and the generation of the results, as the method algorithms are implemented therein.

The results demonstrate that both the MEREK and CoCoFISo methods are effective in addressing the problem and the MadURank achieved its goal. However, we encountered a limitation during this research. This is the unavailability of data.

It would be beneficial for future research to consider additional qualified criteria in the field of education and scientific research, such as the grades of the permanent teaching staff (Higher Education Assistant, Assistants Professors, Professors and Full Professors), the number of scientific publications (international journal, conference...), the number of schools and faculties, and so forth.

Furthermore, in conjunction with the Malagasy government's initiative to establish local public universities in each of Madagascar's regional capitals, it will be feasible to incorporate these new public institutions into the existing network of public institutions in Madagascar (Higher Institutes of Technology: Furthermore, the potential for greater openness could be achieved by including private higher education institutions that already exist in Madagascar, such as those in Antananarivo, Antsiranana, and Ambositra.

In any case, the MadURank that has been developed can be used regardless of the criteria employed or the number of universities included.

It is important to note that the forthcoming version of MadURank will allow for a subjective approach to be taken when calculating the weights of the criteria. This allows decision-makers to prioritise the criteria according to their own preferences, thereby facilitating a new classification of the universities in relation to the criteria they consider to be of particular importance.

Each manuscript should conclude with a section of between 250 and 450 words. This should present the major outcome of the work, highlighting its importance, limitations, relevance, applications and recommendations. The conclusion should be presented in a continuous manner with coherent, flowing sentences. It should include a comprehensive overview of the research work's main outcome, its practical applications, potential limitations, and recommendations for future work. It is not permissible to include any subheadings, citations, references to other sections of the manuscript, or point lists within the conclusion. In the concluding paragraph, the author presents a description of the aforementioned topic.

Data Availability

The data used in this study are available on the website of the Institut National de la Statistique de Madagascar (INSTAT). For further details, please refer to the link below: <https://www.instat.mg/statistiques/education>.

It should be noted that the data published by INSTAT are in their original, unprocessed form; however, we have processed them in order to facilitate our research.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

Funding Source

None

Authors' Contributions

Rôlin Gabriel Rasoanaivo was responsible for selecting the methods to be employed, developing MadURank and drafting the manuscript. Joseph Alphonse Tata was tasked with data collection and data processing. Rasoanaivo and Tata collaborated on testing and validating the result of MadURank, validating the manuscript, and revising the manuscript.

Acknowledgements

We would like to express our gratitude to Mrs Pascale Zaraté, Professor at the Université Toulouse Capitole and Head of the Artificial Intelligence Department at the Institut de Recherche en Informatique de Toulouse in France, for her invaluable guidance and supervision throughout our research.

Furthermore, we extend our gratitude to the team at INSTAT and MESUPRES in Madagascar for making the data publicly available, thus facilitating our research endeavours.

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