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Decision Support System Using Centroidous and CoCoFISo Methods for Analyzing Resource Availability in High Schools

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ABSTRACT

The allocation of educational resources significantly impacts student enrollment and success across different levels of study. This study examines the distribution of human and material resources in Madagascar's high schools, administered by the Regional Directorates of National Education (DRENs). To address inequities in resource allocation, we propose a systematic evaluation of the 23 DRENs using three contextual approaches: rural, urban, and a hybrid model. We developed a multi-criteria decision support system (MADREN) to assess DRENs annually, incorporating nine criteria: four measuring material resources, three evaluating human resources, and two tracking student success. The Centroidous method was employed to determine criterion weights, while the Combined Compromise for Ideal Solution (CoCoFISo) method ranked the DRENs. Results revealed consistent top performance by the Analamanga DREN across all contexts, while the Ihorombe (urban), Melaky (rural), and hybrid models consistently ranked lowest. The rankings highlight disparities in resource availability, with materially advantaged DRENs outperforming others. Crucially, the study identifies significant inequities in current resource distribution. This research provides policymakers with a data-driven tool to optimize resource allocation, ensuring equitable opportunities for student success across Madagascar's high schools. The MADREN system offers a replicable framework for evidence-based educational planning in resource-constrained settings.

1. Introduction

During the 2022-2023 academic year, the student population of Madagascar totalled 7,737,140, encompassing all levels of education from pre-school to high school. The distribution of students across these institutions is as follows: 12.79% in pre-schools, 66.09% in primary schools, 15.53% in secondary schools and 5.58% in high schools. The net enrolment rate for each of these categories is as follows: 36.22% in pre-schools, 97.97% in primary schools, 27.40% in secondary schools and 11.95% in high schools. This enrolment percentage is calculated based on the following age groups: 3 to 5 years old in pre-school, 6 to 10 years old in primary school, 11 to 14 years old in secondary schools and 15 to 17 years old in high schools.

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In Madagascar, the Ministry of National Education (MEN) is responsible for implementing the State's General Policy on National Education and Literacy from pre-school to high school. This is done in order to achieve the strategic objectives set out by the Ministry and to ensure that all students are provided with a quality education. In order to accomplish this mission, Regional Departments of National Education (DREN) have been decentralised in various regions of Madagascar. These departments are responsible for implementing the Ministry's policy on education, training and literacy in accordance with the standards and educational objectives set by the Ministry, while also taking into account the specific characteristics of each Region. A school district (CISCO) is a local administrative unit within each district of Madagascar, operating under the authority of the DREN. A total of 114 of these entities are distributed across the various DRENs. So, the education system within each CISCO encompasses pre-schools, primary schools, secondary schools and high schools.

To assist the Ministry's managers in making decisions, we have taken the initiative of highlighting the data provided by the statistics department of the Ministry's educational planning directorate. Our study revealed that, since the 2000-2001 academic year, a document of a statistical nature, referred to as an "Annuaires statistiques"1, has been published on an annual basis by the MEN. In particular, it includes the quantity of data available from CISCOs and DRENs according to their locations (urban, rural), sectors (public, private) and schools (pre-schools, primary schools, secondary schools and high schools). It is asserted that the document under consideration is a rich source of information. Consequently, this study focuses on the most recent version of this document for the year 2022-2023 [1]. It was thus of interest to examine the role of the DRENs, which serve to unite the CISCOs and are of significant consequence in the realisation of the MEN's stated objectives.

The following research questions (RQ) will be addressed:

RQ1: Can the DREN be evaluated on the basis of the data contained in this document, which is published annually?

RQ2: What is the evaluation method that takes into account the DREN evaluation criteria?

RQ3: Why not propose software to implement the DREN evaluation method?

In response to RQ1, we have identified the possibility of evaluating the DRENs in different ways.

The initial step is to select the evaluation criteria. Therefore, the DREN can be evaluated according to the four types of school: pre-school, primary schools, secondary schools and high schools. Subsequently, these schools are situated within both the public and private sectors, and are located in both urban and rural locations. For each of these schools, a various of data sets are available, including the number of students enrolled by gender, the number of classrooms, the number of seats on the benches, the number of teachers, the number of administrative staff, the number of students repeating a year, the number of students registered for national examinations, the number of students admitted to examinations, and so forth. Consequently, a comprehensive range of evaluation criteria for the DRENs is available. Later in section 3 of this paper, the selection of evaluation criteria for these DRENs will be presented.

Given the diversity of DREN evaluation criteria, it is necessary to have a method that takes this situation into account to respond to RQ2. Multi-criteria decision-making methods were chosen because they are used in the literature to solve selection, ranking and allocation problems [2–7].

The algorithm for the selected method will then be implemented in a decision support system to enable the Ministry's future user to familiarise themselves with today's new information and communication technologies. The RQ3 will be resolved through the implementation of this software.

In order to achieve this objective, the article is structured as follows. Following this introduction, which constitutes the first part, a review of the literature will be presented in the second part. Section

[1] https://www.education.gov.mg/ressources/annuaires-statistiques/

three then deals with the research methodology that we will apply. This will give us precise information on how our research will be carried out, the method we will opt for, as well as the algorithm and software we have created. In the fourth part, we will look at the experimental information, the results and their analysis. Finally, in the fifth and last part, we will look at a discussion, a conclusion and the possibility of future work.

2. Literature Review

We were motivated by recent work using multi-criteria decision-making methods in the field of education that we are going to quote some of them. In Malaysia, ten schools were subjected to an academic performance study utilising the Fuzzy VIKOR method [8]. The selected criteria encompassed four subjects across five distinct levels of study. The findings demonstrated that the proposed method was effective in ranking schools, offering valuable insights that could inform decision-making by the head of the Ministry of Education in Malaysia.

The current situation is such that parents and students are experiencing concern with regard to the selection of an appropriate educational establishment. The study in question covered 2,000 secondary schools in Bangladesh, but three were selected for the purposes of illustration [9]. The BWM method was employed to rank six criteria according to the level of user intervention, while the AHP method was utilised to rank the secondary schools. Based on the results, the user was able to make an informed decision regarding the most appropriate school.

One such study employed the extended TOPSIS method to compare European Union member countries in terms of their implementation of strategic objectives in the field of education [10]. This approach was used to evaluate the sustainability of development in these countries. Three evaluation modalities have been implemented: the classic approach, the approach based on the European Union target and the approach based on the national and European Union target. In all three modalities, and among the 28 member states of the European Union, Denmark was ranked first, thus demonstrating the efficacy of the aforementioned approaches.

A study was conducted in India to investigate the quality of websites in the field of school education, given the growing trend of their creation [11]. Multi-criteria decision-making methods, including the Linear Weight Model and TOPSIS, were employed to assess ten competency criteria. The findings revealed that performance and quality criteria are often overlooked when a school education board has a presence on a website.

A comprehensive review of the application of multi-criteria decision-making methods in higher education was conducted by Yüksel and colleagues [12]. A total of 72 works were identified, spanning the period from 1983 to 2020. These works encompass a diverse range of contexts in which MCDMs have been applied, including staff selection, higher education performance, student absence, course selection, student satisfaction, department selection, teacher performance, and others. The authors employed a range of methods throughout the course of their work, including AHP, FAHP, ANP, TOPSIS, FTOPSIS, VIKOR, HIBRIT and Diger. Of these, AHP was the most frequently utilised.

The deployment of multicriteria decision-support methodologies in the field of education serves to illustrate the significance of their utilisation in this domain. This led us to implement them in the case of Madagascar during the evaluation of the DRENs. Nevertheless, numerous multi-criteria decision-making techniques have been proposed in the literature. Which approach should be selected?

It is our intention to adopt a more contemporary technique that has already been successfully tested. Consequently, it is necessary to utilise two methods to assess the weight of the criteria and rank the DRENs. We therefore believe that the Centroidous and CoCoFISo methods meet our requirements.

The two methods under discussion were developed in 2024, with Centroidous being used to calculate the importance of the criteria and CoCoFISo being used to rank the alternatives. Centroidous was able to calculate the weights of the criteria when it was created, in order to prioritise eight criteria for ranking seven mobile phones [13]. Subsequently, the author compared the weights of the Centroidous criteria with those of the CRITIC, Entropy, Standard deviation, Mean and MEREC methods. A recent study [14] used the Centroidous method in conjunction with the MOORSA method to evaluate unmanned aerial vehicles, establishing a hierarchy of three relevant criteria and ranking five vehicles using the MOORSA a method. The author then performed a simulation with six different data sets to obtain the variation of the ranks.

In contrast, the CoCoFISo method was utilised to address the student housing allocation problem through the application of two concrete cases [15]. The author then proceeded to compare the outcomes obtained with those of the PROMETHEE, TOPSIS and WSM methods. Subsequently, a variation of twenty weights of the criteria was employed to ascertain the stability of the ranks obtained through this method. The results demonstrated the efficacy of CoCoFISo in resolving the aforementioned problem. Two further recent success stories of the CoCoFISo method have been documented in the literature: the first addresses the issue of ranking universities [16], while the second evaluates regions in the field of employment [17]. Therefore, this research will, for the first time, combine the application of the Centroidous method with the CoCoFISo method. In this paper we will find the effectiveness of these two methods in solving this case of DREN classification.

In the contemporary era, characterised by the prevalence of information and communication technology, the proposal of a decision support system for the Ministry of Education is imperative. The prevailing tendency in the current academic discourse is to establish a decision support system that employs multi-criteria methods to facilitate decision-making processes. The existing literature has documented the presence of multi-criteria decision support systems in the field of education [18–22]. This paper presents a multi-criteria decision support system that has been developed for this study. The system, designated as MADREN (an acronym for Madagascar, Direction Régionale de l'Éducation Nationale), is designed to assist managerial decision-making processes by providing a framework for comparing the status of DRENs. The software MADREN employs two primary methodologies: Centroidous and CoCoFISo, to facilitate the evaluation of DRENs. It offers the possibility of classifying these DRENs according to several options, including by location (urban, rural), by type of school (pre-schools, primary schools, secondary schools, high schools), by sector (public, private) and overall.

3. Research Methodology

3.1. Research Process

The research was conducted in accordance with a defined methodology, comprising a number of distinct stages. This commenced with the definition of the overarching subject matter, namely, access to decision support for the Ministry of National Education. In particular, our objective was to assist decision-makers within this Ministry and the regional directorates of national education in their decision-making processes. This will firstly enable them to gain a deeper comprehension of the existing situation and secondly to contemplate potential avenues for improvement. Consequently, we conducted a comprehensive search for data pertaining to this Ministry, which we located on the website of the Institut National de la Statistique de Madagascar (INSTAT). The site encompassed a vast array of information, necessitating the identification of that which was pertinent and aligned with our research parameters. Given the comprehensive nature of the data set, a process of global information extraction was undertaken. Once the data had been made available, the methods to be employed were selected. The methods were initially evaluated in MS Excel according to the data

processed. An initial result was produced. Subsequently, the model of the multi-criteria decision support system was developed by implementing the algorithms of the selected methods. A prototype was constructed and the data was organised for testing of the software. Furthermore, the results obtained from the software were also considered, constituting our second result. Following a comparison of the two results, it was evident that they were identical. The findings from the software were then considered and analysed, marking the beginning of the article writing process.

This involved a literature review, the determination of the title, and the drafting of the article itself. To conclude, the decision was made to select the journal in which to publish the article and submit it. The research process is summarised in Figure 1 below.

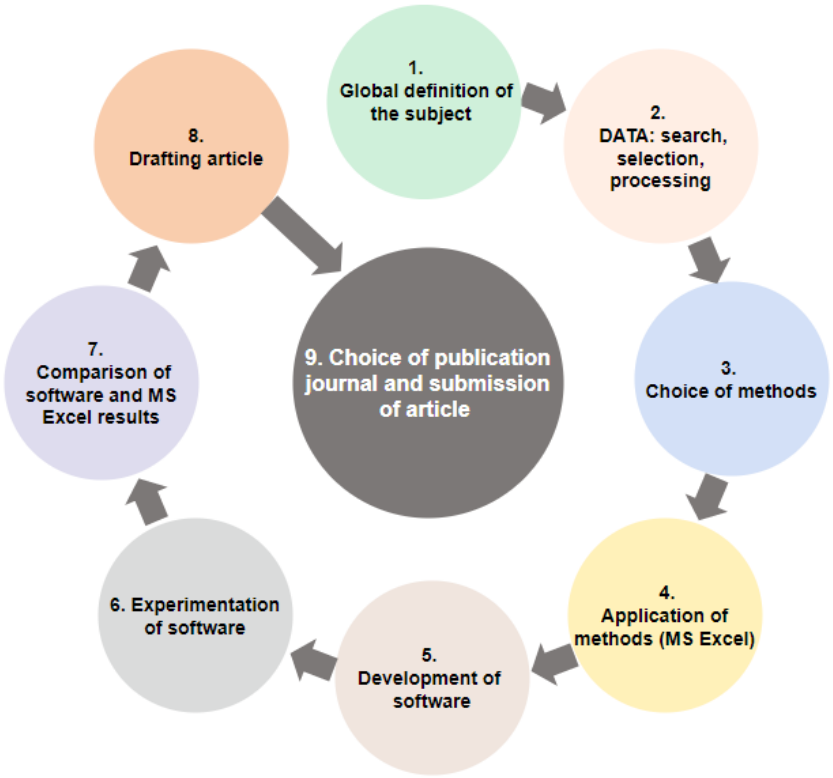


Fig. 1. Research process

3.2. Research Method

To employ multi-criteria decision-making methodologies, a defined process must be followed. This begins with an understanding of the problem to be solved, the identification of the criteria to be implemented and the determination of the alternatives to be evaluated. Subsequently, the methods to be applied are selected. Once the methods have been selected, the criteria weights are calculated and the alternatives evaluated. In light of the aforementioned process, the extant literature proposes a plethora of multi-criteria decision-making methods. However, we have elected to access and test the most recent methods, which were developed in 2024. Consequently, to calculate the criteria weights, we will use the Centroidous method [13]. While to evaluate the alternatives, we will apply the Combined compromise for ideal solution (CoCoFISo) method [15]. This represents a novel approach, as it is the inaugural instance of these two methodologies being employed in conjunction with one another. To apply these two methods, it is necessary to assume that the Eq. (1) performance matrix (X), which is composed of n criteria and m alternatives, is available.

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{13} \ldots & x_{1n} \\ x_{21} & x_{22} & x_{23} \ldots & x_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \\ x_{m1} & x_{m2} & x_{m3} \ldots & x_{mn} \end{bmatrix} \quad (1)$$

So, the algorithm for each method will be presented below. We shall first consider the method for calculating the criteria weights.

3.2.1. Centroidous method

The Centroidous method is one of the techniques employed for the classification of the criteria pertaining to the objective family. The methodology is based on the search for criteria that are at a minimum distance from their group centre. As a criterion moves closer to the group centre, its weight increases. The algorithm is based on five stages. The main objective is to normalize the performance matrix. Next, the centre point of the group of criteria is determined. Also, the Euclidean distance of the criteria from the centre of gravity of their group is sought. In addition, the Euclidean distance between each criterion is reduced as much as possible. Finally, the weights of the criteria are obtained by normalising the reduced Euclidean distance. The calculation process is outlined in detail in Eq. (2) to Eq. (6) below [13].

- Performance matrix normalization

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

- Centre of gravity

$$c_i = \frac{1}{n} \sum_{j=1}^{n} \widetilde{x_{ij}} \quad (3)$$

- Euclidean distance

$$d_j = \sqrt{\sum_{i=1}^{m} (\widetilde{x_{ij}} - c_i)^2} \quad (4)$$

- Euclidean distance normalization

$$\widetilde{d_j} = \frac{j^{\min (d_j)}}{d_j} \quad (5)$$

- Criteria weight

$$w_j = \frac{\widetilde{d_j}}{\sum_{j=1}^{n} \widetilde{d_j}} \quad (6)$$

We will now proceed to examine our second method, which is concerned with the evaluation of the alternatives.

3.2.2. Combined compromise for ideal solution (CoCoFISo) method

The CoCoFISo method was developed in response to the shortcomings of the combined compromise solution method, which resulted in the generation of erroneous algorithms in two distinct real-world scenarios [15]. CoCoFISo is an approach that seeks to integrate disparate methodologies in order to identify an optimal compromised solution. The algorithm begins by normalizing the performance matrix in order to standardise the data, due to the diversity of measurement units. Two sequences of comparability are then calculated using the weighted sum and weighted product methods. As a result, these two series undergo three separate operations to obtain three different pre-results. Finally, these are grouped together to obtain the final score. The optimal

option is the one with the highest final score. Eq. (7) to Eq. (13) will be employed in order to arrive at a solution via the CoCoFISo method.

- Performance matrix normalization

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m}(x_{ij})^2}} \tag{7}$$

- comparability sequence weighting

$$S_i = \sum_{j=1}^{n}(w_j r_{ij}) \tag{8}$$

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

- Deduction of aggregation strategies from comparability sequences

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m}(P_i + S_i)} \tag{10}$$

$$k_{ib} = \left(\frac{S_i + P_i}{1 + \frac{S_i}{1+S_i} + \frac{P_i}{1+P_i}} \right) \tag{11}$$

$$k_{ic} = \frac{\lambda(S_i) + (1-\lambda)(P_i)}{(\lambda \max_i S_i + (1-\lambda)\max_i P_i)};\ 0 \le \lambda \le 1 \tag{12}$$

- Determining the final score

$$k_i = (k_{ia}k_{ib}k_{ic})^{\frac{1}{3}} + \frac{1}{3}(k_{ia} + k_{ib} + k_{ic}) \tag{13}$$

3.3. MADREN Implementation

MADREN is the acronym for "*Madagascar, Direction Régionale de l'Education Nationale*", which may be translated as regional directorate of national education in Madagascar. It is a multi-criteria decision-making system that implements the algorithms of the Centroidous and CoCoFISo multi-criteria methods. The system's objective is to evaluate the performance of Madagascar's regional directorates of national education (DREN) in terms of the accessibility of resources (human and material) and academic outcomes in primary, secondary and high schools. The intention is to assist those responsible for each department in making decisions based on their circumstances. To enhance development policy, it is may be vital for the Ministry of Education to ascertain the ranking of each regional directorate, in order to facilitate decision-making. In this sub-section, we will explain how this software works in part.

Figure 2 below illustrates the MADREN use case diagram, which provides the user with the opportunity to interact with the system. In summary, the user has the option of interacting in three different situations: entering data, viewing the data or results, and printing the data or results. All interaction with the system requires authentication in order to identify users.

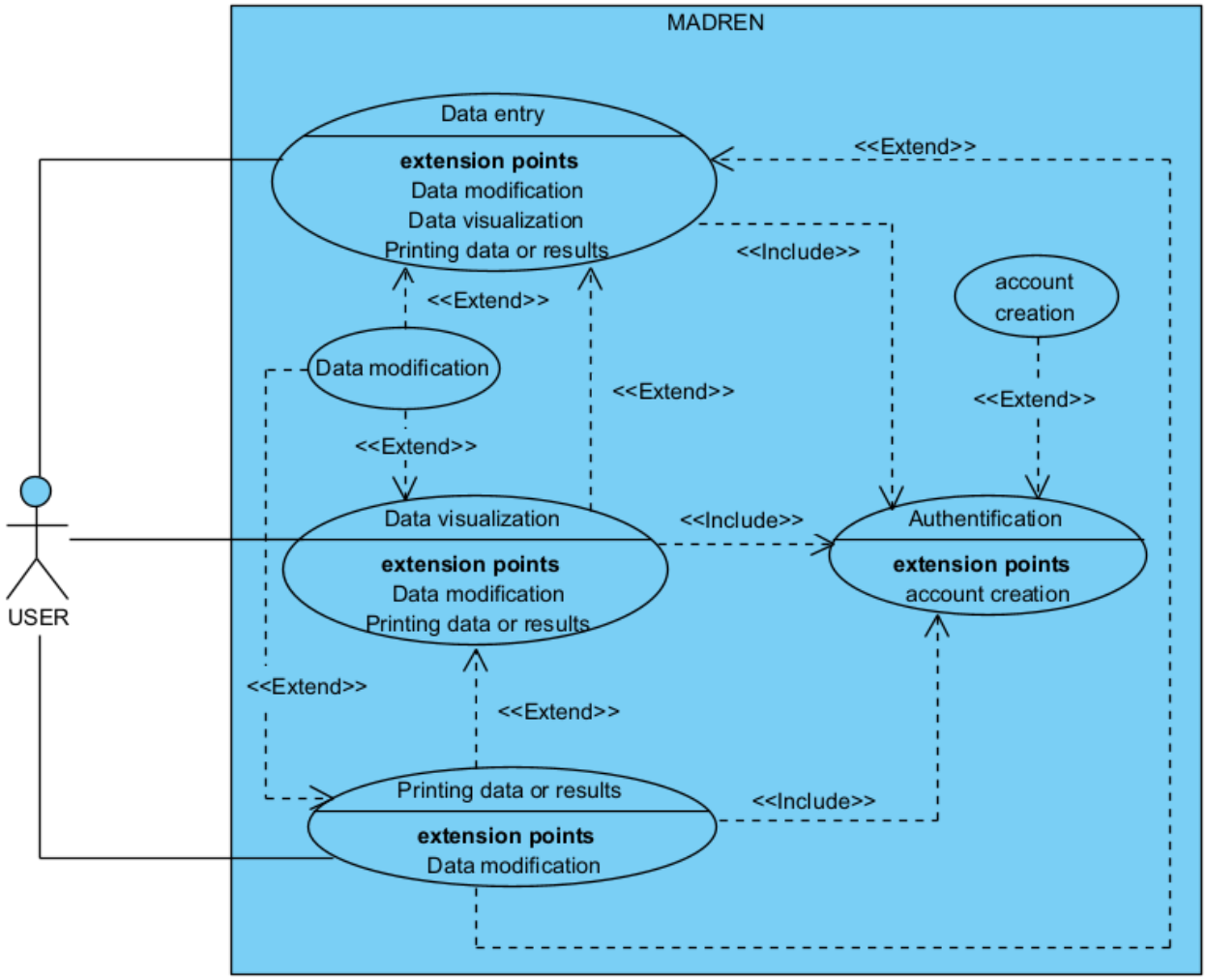


Fig. 2. MADREN use case diagram

After successful login, the user can access the main menu shown in Figure 3 below. This menu presents the various options for using MADREN that we have already mentioned. The menu contains six distinct data entry buttons, including DREN, Establishment, Residence, Status, Criteria and Performance matrix. The latter button enables the direct viewing of results, such as the criteria weights and DREN ranks. To guarantee the optimal functionality of the system, it is essential to enter the six types of data in a consecutive manner. The following data must be entered:

- **DREN**, which denotes the various regional directorates of national education.
- **Establishment**, which identifies three types of educational establishment, namely primary, secondary and high schools.
- **Residence**, which determines the location of schools, including rural, urban or both.
- **Status**, which indicates whether the school is public or private.
- **Criteria**, which records the various DREN evaluation objectives.
- **Performance matrix**, which lists the values of the criteria for each type of DREN school according to residence and status.

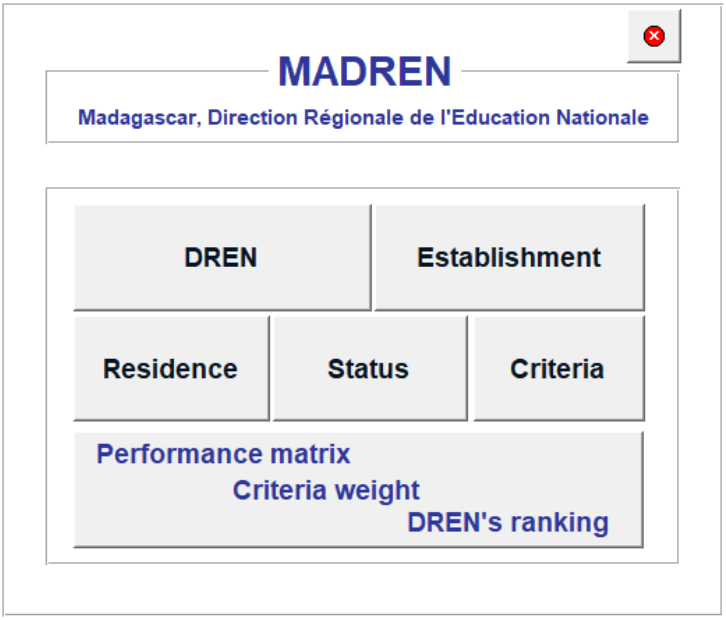


Fig. 3. MADREN main menu

To assist the user in entering data into MADREN, Table 1 below provides a data dictionary. This indicates for each figure the title, type and description of the data to be entered.

Table 1
Data dictionary

Button	Title	Type	Description
DREN	ID DREN	Short text	Unique DREN identification
	NAME	Short text	DREN's name
Establishment	ID establishment	Numeric	Unique school type identification
	Category	Short text	Category of school type by identification
Residence	ID residence	Short text	Unique residence identification
	Location	Short text	Location of school type
Status	ID status	Short text	Unique status identification
	Status establishment	Short text	Status of school type
Criteria	ID criteria	Short text	Unique criteria identification
	Criteria	Short text	School assessment criteria
	Description	Long text	Improper information on the criteria
Performance matrix	Choose location	Short text	Location of school type
	DREN	Short text	DREN's name
	Criteria*1*, … criteria*n*	Numeric	Value of each criterion for each DREN

As evidenced in Table 1, each form necessitates the input of two pieces of information pertaining to the DREN, establishment, residence, and status. In order to complete the requisite criteria three pieces of information are required. It is imperative that the information on the five aforementioned forms be completed before proceeding to enter the data in the performance matrix. Consequently, the performance matrix automatically records the data entered previously and requests additional specific information. It has been observed that this form requires a considerable amount of information to be completed. Therefore, we have provided an activity diagram, illustrated in Figure 4 below, to assist the user. It provides a comprehensive explanation of the process to be followed in integrating the data into the performance matrix.

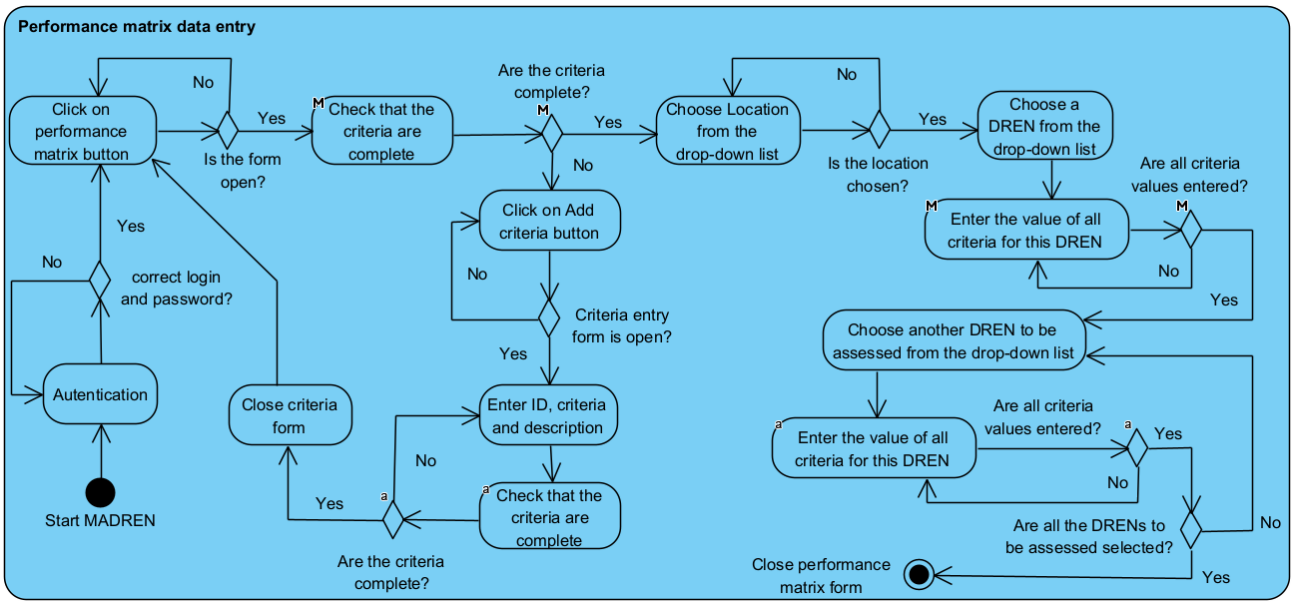


Fig. 4. Activity diagram of performance matrix data entry

Once the data for the performance matrix has been entered, the results may be viewed. Two results will be available: the calculation of the importance of the criteria, displaying the respective weights, and the classification of the DRENs. The MADREN system produces disparate results contingent on the geographical location of the establishment in question, as well as the specific weights attributed to the criteria and the ranking of the DREN.

This allows the results to be visualised using the performance matrix button, the criteria weight and the DREN's ranking. Upon opening the form, the user first selects the location from the drop-down list. They then have the option of visualizing either on the criteria weight or the DREN rank, depending on the desired result.

The MADREN experimental data may now be subjected to analysis and evaluation in order to ascertain the resulting outcomes.

4. Data Set, Results And Analysis

This section will initially present the experimental data, comprising the evaluation criteria and the DRENs to be classified. Subsequently, the data will be entered into MADREN and the resulting data set will be analyzed.

4.1. Data Set

We have chosen data from the "Annuaire statistique national" 2022-2023, a document published by the Ministry of National Education in 2023 [1]. This yearbook is presented on the website of the

National Institute of Statistics of Madagascar (INSTAT). This document presents data collected from schools in operation, broken down by level of education and sector of activity. This document is of significant pedagogical value.

The document provides information on a range of educational levels, including pre-school, primary, secondary and high school, whether private or public. It also includes various summaries. For the purposes of this study, we are focusing specifically on data relating to public high schools. Also, all the data are provided by the DREN and by school district to each DREN in this document. Consequently, we have decided to select the data presented in the DRENs for this first experiment of MADREN system.

The data for public high schools, disaggregated by DREN, remains comprehensive. For instance, the number of students per DREN is initially presented by location, then by class. From the first class onwards, the presentation is disaggregated by baccalaureate option up to the terminal class. Consequently, the data have been processed to obtain cumulative data. In consequence of the above, nine criteria have been identified for the evaluation of publicly funded high schools by DREN. The availability of the aforementioned criteria allows for the identification of three potential locations for the high schools in question, namely those situated in urban areas, in rural areas, and in both these areas combined. The nine criteria will be described below.

- Students: it's the total number of students registered at all academic levels. The data set are initially presented according to the following variables: DREN, location, class, baccalaureate option and gender. The data was then subjected to aggregation and grouping according to DREN and location.

$$STUDENTS = \sum Students\ registered \tag{14}$$

- Success (Admission of students to higher classes): the document makes reference to the number of students repeating their studies (REPEATER). The distribution of the aforementioned students was identical to that of the registered student population. Nevertheless, it is the number of students admitted to higher classes that is of interest. The initial stage of the data processing involves the grouping of the data according to the DREN and location. Subsequently, the number of students repeating their studies was deducted from the total number of students registered, thus obtaining the number of students admitted to higher classes.

$$\boldsymbol{SUCCESS} = STUDENTS - REPEATER \tag{15}$$

- Classroom: the documents delineate a variety of classroom configurations; however, our decision was to select the total number of classrooms that are in optimal condition.
- Bench Table: they are distinguished by the number of seats (SEATS) they accommodate, which can range from one to five. In the document, the table-bench numbers are provided irrespective of the number of seats. To ascertain the total number of seats, we have multiplied the bench tables by their respective seat numbers and subsequently added them together. So, the bench table criterion here therefore means the total number of places available to students.

$$BENCH\ TABLE = \sum(SEATS * number\ of\ bench\ table) \tag{16}$$

- Blackboard: this is the total number of existing blackboards.
- Baccalaureate: it refers to the percentage of students who were admitted to the Baccalaureate examinations in 2022, across all available options, including A, C, D, L, S, and

OSE. The initial data were expressed as the number of students admitted by option and by gender; however, for the purposes of this analysis, they have been processed in order to obtain this percentage. To achieve this, we divided the number of students admitted to the baccalaureate exams (ADMITTED) by the number registered for the exams (REGISTERED).

$$BACCALAUREATE = \frac{ADMITTED \times 100}{REGISTERED} \quad (17)$$

- Teacher: This is the ratio student-teacher which represents the number of students taught by one teacher. The document provides data on the number of teachers according to their status. When processing the data, the STUDENTS was divided by the total number of teachers (TOTAL TEACHER).

$$TEACHER = \frac{TOTAL\ TEACHER \times 100}{STUDENTS} \quad (18)$$

- Staff: it represents the ratio of students to administrative and technical staff. This is the number of students cared for by an administrative and technical staff. The raw data show the total number of administrative and technical staff. To obtain the ratio, we divided STUDENTS by the total number of administrative and technical staff (TOTAL STAFF).

$$STAFF = \frac{TOTAL\ STAFF \times 100}{STUDENTS} \quad (19)$$

- Manuals: these textbooks are provided by the government to schools for use in all subjects. The textbooks have been aggregated from the initial data set by subject, in order to provide a total for each subject.

The alternatives to be evaluated are the Regional Directorates of National Education (DREN), of which there are twenty-three in each region of Madagascar. The names of these directorates are provided in Table 2 below for reference.

Table 2
Regional Directorates of National Education (DREN)

Regional Directorates of National Education (DREN) of Madagascar					
01DREN	Alaotra Mangoro	09DREN	Atsinanana	17DREN	Itasy
02DREN	Amoron'i Mania	10DREN	Betsiboka	18DREN	Melaky
03DREN	Analamanga	11DREN	Boeny	19DREN	Menabe
04DREN	Analanjirofo	12DREN	Bongolava	20DREN	Sava
05DREN	Androy	13DREN	Diana	21DREN	Sofia
06DREN	Anosy	14DREN	Fitovinany	22DREN	Vakinakaratra
07DREN	Atsimo Andrefana	15DREN	Haute Matsiatra	23DREN	Vatovavy
08DREN	Atsimo Atsinanana	16DREN	Ihorombe		

It is important to note that these DREN will be evaluated based on the above-mentioned nine criteria pertaining to the status of public high schools in rural, urban, and combined areas. Table 3 below present the availability of resources, taking into account all the criteria and the different location of the schools.

Table 3
Availability of resources from public high schools by DREN

DREN	Area	Student	Success	Class	Bench	Board	Bacc	Teacher	Staff	Manuals
	Urban	8 196	94%	49	3 474	92	71%	37,42	117,09	14 162
01DREN	Rural	14 304	93%	125	7 946	188	58%	31,93	164,41	12 861
	All	22 500	93%	174	11 420	280	63%	33,73	143,31	27 023
	Urban	4 857	90%	64	3 419	84	58%	30,55	121,43	9 689
02DREN	Rural	8 498	94%	68	5 431	164	67%	23,94	128,76	5 748
	All	13 355	93%	132	8 850	248	64%	25,98	125,99	15 437
	Urban	25 824	90%	253	17 639	346	60%	31,65	84,67	54 669
03DREN	Rural	39 818	91%	478	27 448	621	48%	24,90	90,91	33 745
	All	65 642	91%	731	45 087	967	53%	27,18	88,35	88 414
	Urban	8 930	91%	68	5 224	95	73%	37,05	146,39	8 131
04DREN	Rural	10 751	93%	62	6 913	156	72%	37,20	199,09	5 208
	All	19 681	92%	130	12 137	251	72%	37,13	171,14	13 339
	Urban	3 095	93%	17	1 561	34	48%	51,58	128,96	1 609
05DREN	Rural	5 268	84%	8	1 552	40	43%	39,91	202,62	2 213
	All	8 363	87%	25	3 113	74	44%	43,56	167,26	3 822
	Urban	4 344	90%	28	1 898	43	72%	39,85	96,53	4 276
06DREN	Rural	5 082	90%	43	2 711	66	47%	28,55	163,94	3 798
	All	9 426	90%	71	4 609	109	59%	32,84	124,03	8 074
	Urban	9 348	93%	41	5 576	90	50%	25,06	67,25	7 310
07DREN	Rural	11 908	87%	85	5 075	125	42%	26,76	141,76	3 073
	All	21 256	90%	126	10 651	215	47%	25,99	95,32	10 383
	Urban	2 710	88%	8	923	32	49%	35,19	112,92	1 972
08DREN	Rural	6 839	88%	55	5 199	105	43%	30,67	170,98	2 903
	All	9 549	88%	63	6 122	137	45%	31,83	149,20	4 875
	Urban	9 392	93%	50	5 544	112	62%	34,15	92,08	24 039
09DREN	Rural	7 694	94%	73	5 110	110	67%	29,14	108,37	7 063
	All	17 086	93%	123	10 654	222	64%	31,70	98,76	31 102
	Urban	1 962	85%	4	987	20	32%	41,74	140,14	490
10DREN	Rural	2 311	94%	18	1 512	40	63%	22,88	144,44	714
	All	4 273	90%	22	2 499	60	47%	28,87	142,43	1 204
	Urban	5 954	91%	77	4 069	89	45%	32,71	100,92	7 972
11DREN	Rural	4 797	92%	47	2 903	73	47%	29,98	119,93	5 029
	All	10 751	92%	124	6 972	162	45%	31,44	108,60	13 001
	Urban	2 036	89%	23	1 192	27	45%	33,38	156,62	2 484
12DREN	Rural	5 809	92%	81	3 725	108	38%	31,92	223,42	3 427
	All	7 845	91%	104	4 917	135	40%	32,28	201,15	5 911

Table 3
Continued

DREN	AREA	STUDENT	SUCCESS	CLASS	BENCH	BOARD	BACC	TEACHER	STAFF	MANUALS
	Urban	14 640	93%	129	7 507	135	60%	43,44	187,69	9 289
13DREN	Rural	4 174	94%	38	2 070	73	44%	25,45	379,45	1 415
	All	18 814	93%	167	9 577	208	56%	37,55	211,39	10 704
	Urban	4 015	81%	40	3 428	60	33%	31,12	97,93	5 600
14DREN	Rural	6 664	89%	40	3 762	79	33%	29,88	201,94	3 312
	All	10 679	86%	80	7 190	139	33%	30,34	144,31	8 912
	Urban	8 255	92%	92	5 305	132	56%	34,40	97,12	11 125
15DREN	Rural	20 891	86%	169	11 477	308	39%	28,50	189,92	12 948
	All	29 146	88%	261	16 782	440	43%	29,95	149,47	24 073
	Urban	1 839	80%	0	880	15	43%	38,31	262,71	1 280
16DREN	Rural	1 853	91%	20	1 034	24	71%	26,47	142,54	1 121
	All	3 692	85%	20	1 914	39	53%	31,29	184,60	2 401
	Urban	5 564	90%	37	2 926	66	42%	31,08	123,64	7 314
17DREN	Rural	6 125	90%	76	3 489	105	42%	24,31	211,21	4 052
	All	11 689	90%	113	6 415	171	42%	27,12	157,96	11 366
	Urban	1 221	96%	4	758	18	74%	31,31	122,10	3 391
18DREN	Rural	1 456	94%	7	686	16	82%	41,60	121,33	537
	All	2 677	95%	11	1 444	34	77%	36,18	121,68	3 928
	Urban	3 353	85%	29	2 000	42	44%	34,57	93,14	1 314
19DREN	Rural	2 928	89%	13	1 652	39	43%	24,61	100,97	2 389
	All	6 281	87%	42	3 652	81	43%	29,08	96,63	3 703
	Urban	14 470	93%	95	7 850	110	68%	64,31	307,87	4 870
20DREN	Rural	8 167	96%	45	4 945	100	63%	31,78	544,47	3 333
	All	22 637	94%	140	12 795	210	67%	46,96	365,11	8 203
	Urban	12 064	91%	98	7 549	138	36%	33,51	114,90	11 892
21DREN	Rural	14 200	91%	123	8 355	186	47%	26,59	202,86	8 352
	All	26 264	91%	221	15 904	324	41%	29,38	150,08	20 244
	Urban	8 422	90%	77	4 260	87	53%	35,09	127,61	10 155
22DREN	Rural	15 577	91%	143	9 811	234	35%	28,53	192,31	16 169
	All	23 999	91%	220	14 071	321	42%	30,53	163,26	26 324
	Urban	3 662	93%	22	1 230	27	43%	52,31	174,38	268
23DREN	Rural	5 549	80%	25	3 230	79	29%	26,81	113,24	831
	All	9 211	85%	47	4 460	106	33%	33,25	131,59	1 099

Let's move on to entering this data into the system.

4.2. Data Entry In MADREN

Figures 5 to 9 below show the basically data we have entered into MADREN. Figure 5 enumerated the twenty-three regional education directorates. Figure 6 illustrates the three types of institution, namely primary schools, secondary school and high school. Figure 7 shows the status of these institutions, whether public or private. Figure 8 displays the locations of these institutions, such as rural, urban and both. Finally, Figure 9 records the nine evaluation criteria.

DREN

ID DREN	NAME
01DREN	ALAOTRA MANGORO
02DREN	AMORON'I MANIA
03DREN	ANALAMANGA
04DREN	ANALANJIROFO
05DREN	ANDROY
06DREN	ANOSY
07DREN	ATSIMO ANDREFANA
08DREN	ATSIMO ATSINANANA
09DREN	ATSINANANA
10DREN	BETSIBOKA
11DREN	BOENY
12DREN	BONGOLAVA
13DREN	DIANA
14DREN	FITOVINANY
15DREN	HAUTE MATSIATRA
16DREN	IHOROMBE
17DREN	ITASY
18DREN	MELAKY
19DREN	MENABE
20DREN	SAVA
21DREN	SOFIA
22DREN	VAKINAKARATRA
23DREN	VATOVAVY

Fig. 5. Data from DRENs

ESTABLISHMENT

ID establishment	Category
1	Pre-school
2	Primary school
3	Secondary school
4	High school

Fig. 6. Data from establishment

STATUS

ID status	Status establishment
PRI	Private
PUB	Public

Fig. 7. Data from status

RESIDENCE

ID residence	Location
ALL	All
RUR	Rural
URB	Urban

Fig. 8. Data from establishment

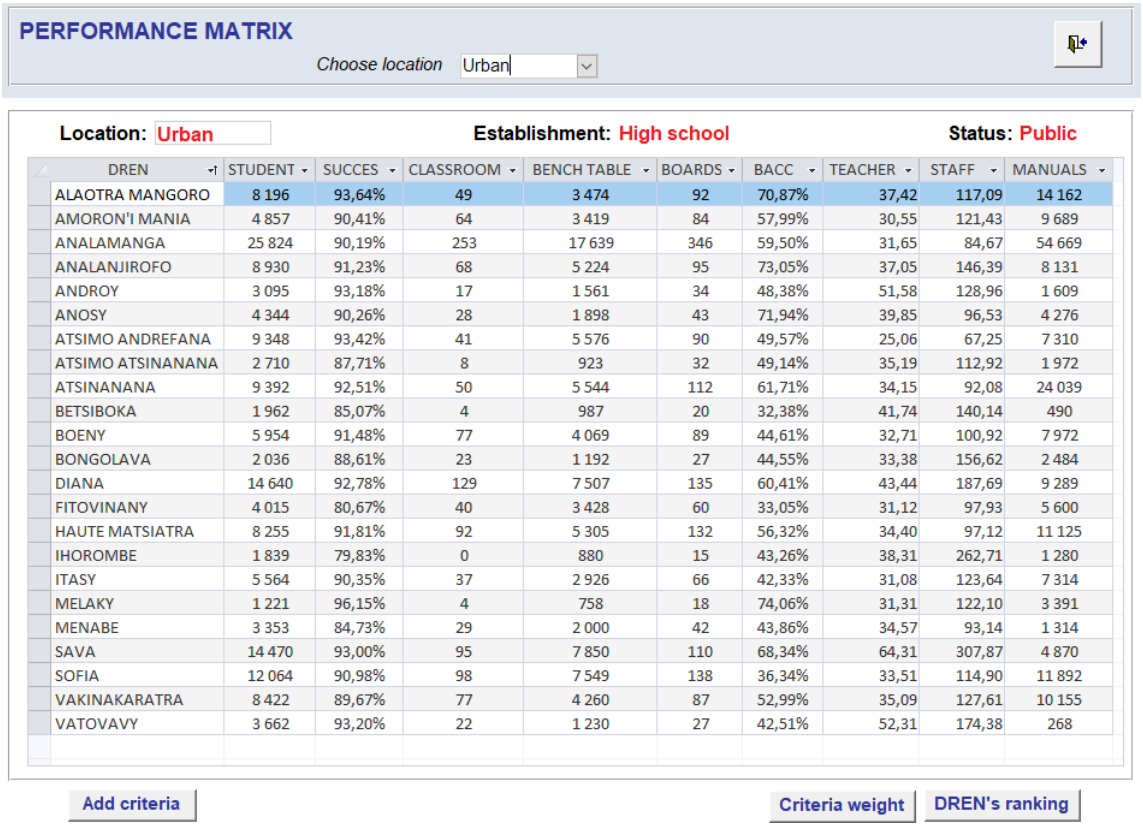
CRITERIA

ID criteria	Criteria	Description
BACC	Baccalaureate	This is the success rate of students in baccalaureate exams
BOARD	Blackboard	This is the whole number of blackboards
CLAS	Classeroom	This is the number of classrooms in good condition
MANU	Manuals	This is the total number of manuels for all subjects combined by th State
STAFF	Staff	This is the students-staff ratio
STUD	Students	This is the numbres of all students registered for a school year
SUC	Success	This is the overall success rate at higher levels of students
TABLE	Bench table	This is the number of place according to the bench table
TEACH	Teacher	This is the students-teacher ratio

Fig. 9. Data from criteria

Once the data were available, we proceeded to enter the performance matrix of the public high school under the responsibility of the DREN, according to each type of location. The performance

matrix for the urban area is illustrated in Figure 10. The rural area is describing by Figure 11, while Figure 12 represents the two zones together.



PERFORMANCE MATRIX

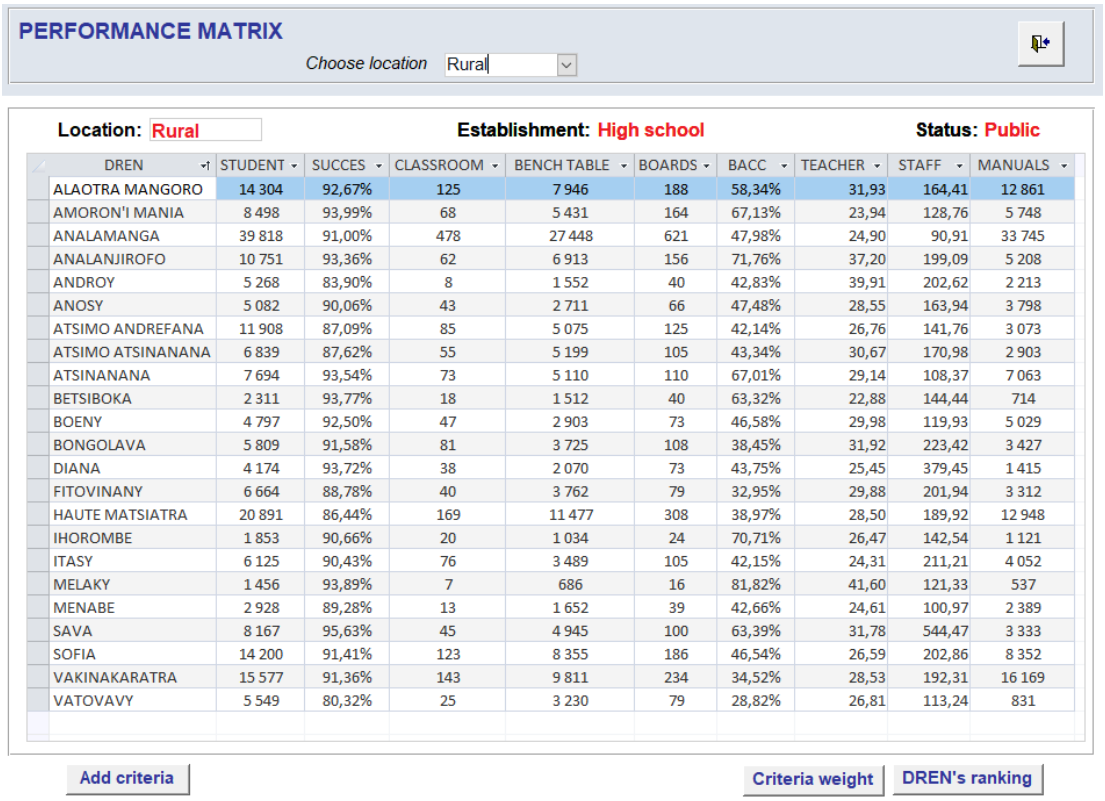
Choose location: Urban

Location: Urban | Establishment: High school | Status: Public

DREN	STUDENT	SUCCES	CLASSROOM	BENCH TABLE	BOARDS	BACC	TEACHER	STAFF	MANUALS
ALAOTRA MANGORO	8 196	93,64%	49	3 474	92	70,87%	37,42	117,09	14 162
AMORON'I MANIA	4 857	90,41%	64	3 419	84	57,99%	30,55	121,43	9 689
ANALAMANGA	25 824	90,19%	253	17 639	346	59,50%	31,65	84,67	54 669
ANALANJIROFO	8 930	91,23%	68	5 224	95	73,05%	37,05	146,39	8 131
ANDROY	3 095	93,18%	17	1 561	34	48,38%	51,58	128,96	1 609
ANOSY	4 344	90,26%	28	1 898	43	71,94%	39,85	96,53	4 276
ATSIMO ANDREFANA	9 348	93,42%	41	5 576	90	49,57%	25,06	67,25	7 310
ATSIMO ATSINANANA	2 710	87,71%	8	923	32	49,14%	35,19	112,92	1 972
ATSINANANA	9 392	92,51%	50	5 544	112	61,71%	34,15	92,08	24 039
BETSIBOKA	1 962	85,07%	4	987	20	32,38%	41,74	140,14	490
BOENY	5 954	91,48%	77	4 069	89	44,61%	32,71	100,92	7 972
BONGOLAVA	2 036	88,61%	23	1 192	27	44,55%	33,38	156,62	2 484
DIANA	14 640	92,78%	129	7 507	135	60,41%	43,44	187,69	9 289
FITOVINANY	4 015	80,67%	40	3 428	60	33,05%	31,12	97,93	5 600
HAUTE MATSIATRA	8 255	91,81%	92	5 305	132	56,32%	34,40	97,12	11 125
IHOROMBE	1 839	79,83%	0	880	15	43,26%	38,31	262,71	1 280
ITASY	5 564	90,35%	37	2 926	66	42,33%	31,08	123,64	7 314
MELAKY	1 221	96,15%	4	758	18	74,06%	31,31	122,10	3 391
MENABE	3 353	84,73%	29	2 000	42	43,86%	34,57	93,14	1 314
SAVA	14 470	93,00%	95	7 850	110	68,34%	64,31	307,87	4 870
SOFIA	12 064	90,98%	98	7 549	138	36,34%	33,51	114,90	11 892
VAKINAKARATRA	8 422	89,67%	77	4 260	87	52,99%	35,09	127,61	10 155
VATOVAVY	3 662	93,20%	22	1 230	27	42,51%	52,31	174,38	268

Add criteria | Criteria weight | DREN's ranking

Fig. 10. Urban performance matrix for public high schools



PERFORMANCE MATRIX

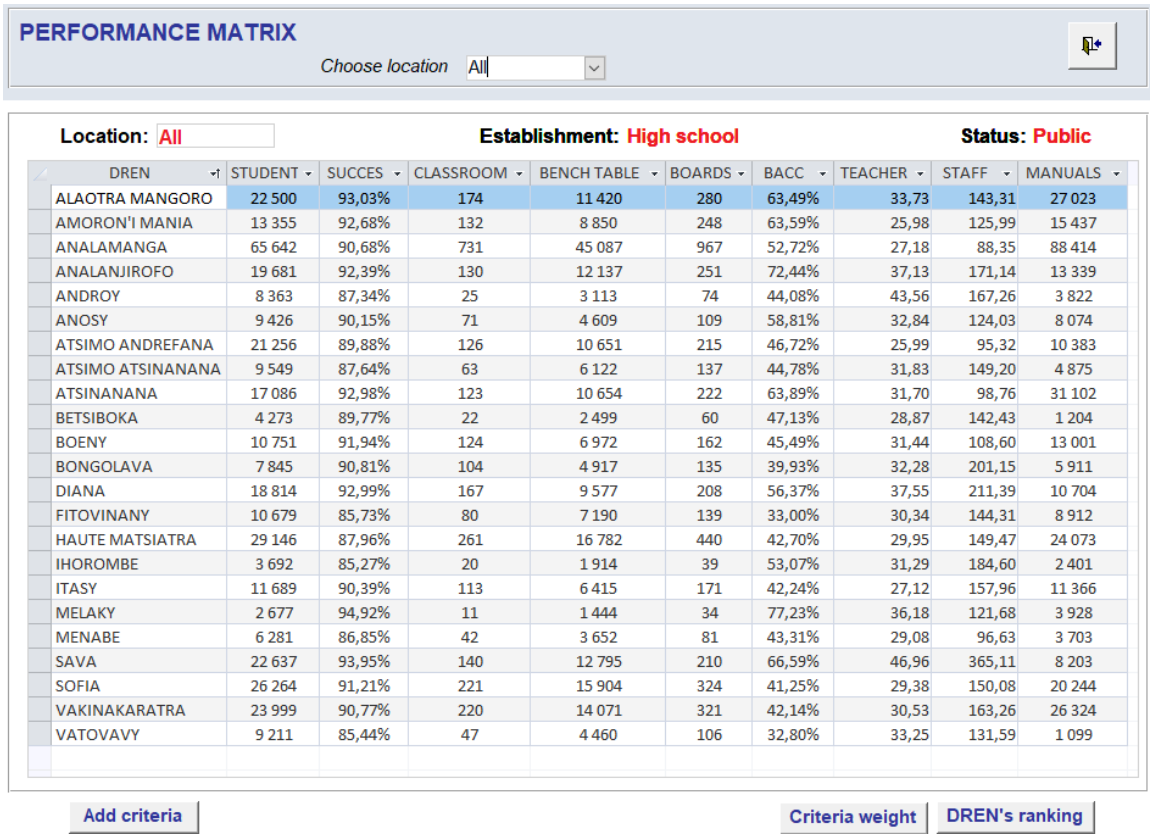
Choose location: Rural

Location: Rural | Establishment: High school | Status: Public

DREN	STUDENT	SUCCES	CLASSROOM	BENCH TABLE	BOARDS	BACC	TEACHER	STAFF	MANUALS
ALAOTRA MANGORO	14 304	92,67%	125	7 946	188	58,34%	31,93	164,41	12 861
AMORON'I MANIA	8 498	93,99%	68	5 431	164	67,13%	23,94	128,76	5 748
ANALAMANGA	39 818	91,00%	478	27 448	621	47,98%	24,90	90,91	33 745
ANALANJIROFO	10 751	93,36%	62	6 913	156	71,76%	37,20	199,09	5 208
ANDROY	5 268	83,90%	8	1 552	40	42,83%	39,91	202,62	2 213
ANOSY	5 082	90,06%	43	2 711	66	47,48%	28,55	163,94	3 798
ATSIMO ANDREFANA	11 908	87,09%	85	5 075	125	42,14%	26,76	141,76	3 073
ATSIMO ATSINANANA	6 839	87,62%	55	5 199	105	43,34%	30,67	170,98	2 903
ATSINANANA	7 694	93,54%	73	5 110	110	67,01%	29,14	108,37	7 063
BETSIBOKA	2 311	93,77%	18	1 512	40	63,32%	22,88	144,44	714
BOENY	4 797	92,50%	47	2 903	73	46,58%	29,98	119,93	5 029
BONGOLAVA	5 809	91,58%	81	3 725	108	38,45%	31,92	223,42	3 427
DIANA	4 174	93,72%	38	2 070	73	43,75%	25,45	379,45	1 415
FITOVINANY	6 664	88,78%	40	3 762	79	32,95%	29,88	201,94	3 312
HAUTE MATSIATRA	20 891	86,44%	169	11 477	308	38,97%	28,50	189,92	12 948
IHOROMBE	1 853	90,66%	20	1 034	24	70,71%	26,47	142,54	1 121
ITASY	6 125	90,43%	76	3 489	105	42,15%	24,31	211,21	4 052
MELAKY	1 456	93,89%	7	686	16	81,82%	41,60	121,33	537
MENABE	2 928	89,28%	13	1 652	39	42,66%	24,61	100,97	2 389
SAVA	8 167	95,63%	45	4 945	100	63,39%	31,78	544,47	3 333
SOFIA	14 200	91,41%	123	8 355	186	46,54%	26,59	202,86	8 352
VAKINAKARATRA	15 577	91,36%	143	9 811	234	34,52%	28,53	192,31	16 169
VATOVAVY	5 549	80,32%	25	3 230	79	28,82%	26,81	113,24	831

Add criteria | Criteria weight | DREN's ranking

Fig. 11. Rural performance matrix for public high schools



DREN	STUDENT	SUCCES	CLASSROOM	BENCH TABLE	BOARDS	BACC	TEACHER	STAFF	MANUALS
ALAOTRA MANGORO	22 500	93,03%	174	11 420	280	63,49%	33,73	143,31	27 023
AMORON'I MANIA	13 355	92,68%	132	8 850	248	63,59%	25,98	125,99	15 437
ANALAMANGA	65 642	90,68%	731	45 087	967	52,72%	27,18	88,35	88 414
ANALANJIROFO	19 681	92,39%	130	12 137	251	72,44%	37,13	171,14	13 339
ANDROY	8 363	87,34%	25	3 113	74	44,08%	43,56	167,26	3 822
ANOSY	9 426	90,15%	71	4 609	109	58,81%	32,84	124,03	8 074
ATSIMO ANDREFANA	21 256	89,88%	126	10 651	215	46,72%	25,99	95,32	10 383
ATSIMO ATSINANANA	9 549	87,64%	63	6 122	137	44,78%	31,83	149,20	4 875
ATSINANANA	17 086	92,98%	123	10 654	222	63,89%	31,70	98,76	31 102
BETSIBOKA	4 273	89,77%	22	2 499	60	47,13%	28,87	142,43	1 204
BOENY	10 751	91,94%	124	6 972	162	45,49%	31,44	108,60	13 001
BONGOLAVA	7 845	90,81%	104	4 917	135	39,93%	32,28	201,15	5 911
DIANA	18 814	92,99%	167	9 577	208	56,37%	37,55	211,39	10 704
FITOVINANY	10 679	85,73%	80	7 190	139	33,00%	30,34	144,31	8 912
HAUTE MATSIATRA	29 146	87,96%	261	16 782	440	42,70%	29,95	149,47	24 073
IHOROMBE	3 692	85,27%	20	1 914	39	53,07%	31,29	184,60	2 401
ITASY	11 689	90,39%	113	6 415	171	42,24%	27,12	157,96	11 366
MELAKY	2 677	94,92%	11	1 444	34	77,23%	36,18	121,68	3 928
MENABE	6 281	86,85%	42	3 652	81	43,31%	29,08	96,63	3 703
SAVA	22 637	93,95%	140	12 795	210	66,59%	46,96	365,11	8 203
SOFIA	26 264	91,21%	221	15 904	324	41,25%	29,38	150,08	20 244
VAKINAKARATRA	23 999	90,77%	220	14 071	321	42,14%	30,53	163,26	26 324
VATOVAVY	9 211	85,44%	47	4 460	106	32,80%	33,25	131,59	1 099

Fig. 12. All performance matrix for public high schools

This availability of the performance matrix permits the visualisation of the results. Let's move on to these results.

4.3. Results

This section presents the experimental results obtained from the MADREN software. Following the application of multi-criteria decision-making methods, the weights of the criteria will be presented using the Centroidous method, while the ranks of the DRENs will be presented using the CoCoFISo method. However, given that three different performance matrixes are available, depending on the location of the public high schools (urban, rural and all), the results will be presented according to these locations.

4.3.1. Criteria weight and ranking of DRENs by public high schools in urban location

In this context, we will present the assigned weights for each of the criteria and the resulting rank of the DREN for the public high schools situated in the urban area, according to the performance matrix illustrated in Figure 10.

Centroidous method was able to determine the relative importance of the criteria. The three most significant criteria for evaluating the quality of educational institutions in urban areas are the number of students enrolled, the number of blackboards available for use, and the number of seats represented by the bench table. Four criteria are assigned the same weighting, namely the success rate in the promotion exams, the number of classrooms, the success rate in the Baccalaureate exams and the students teacher ratio. Conversely, the criteria deemed to be of lesser importance are the ratio of students to staff and the number of manuals supplied by the State to the high schools. In terms of value, the criteria are assigned weights ranging from 0.17 to 0.15, 0.13 to 0.10, 0.07 to 0.06.

In consideration of the significance of the evaluation criteria and the performance of each DREN in relation to all the criteria, CoCoFISo was able to assess them for high schools situated in urban areas. So, the Analamanga DREN was the most highly-ranked, followed by Sava DREN and Diana DREN in the second place. Then, Sofia DREN was placed fourth, with three DRENs tied for fifth place: Haute Matsiatra DREN, Atsinanana DREN and Analanjarafo DREN. The two DREN Vakinakaratra and DREN Alaotra Mangoro were placed eighth. The Atsimo Andrefana and Boeny DRENs are positioned in tenth place. The following DRENs are ranked successively from twelfth to twenty-third: Amoron'i Mania DREN, Itasy DREN, Fitovinany DREN, Anosy DREN, Menabe DREN, Androy DREN, Bongolava DREN, Atsimo Atsinanana DREN, Melaky DREN, Betsiboka DREN, Vatovavy DREN and Ihorombe DREN. Figure 13 illustrates the weights of the nine criteria as determined by the Centroidous method, while Figure 14 depicts the classification of the twenty-three DREN according to the CoCoFISo method.

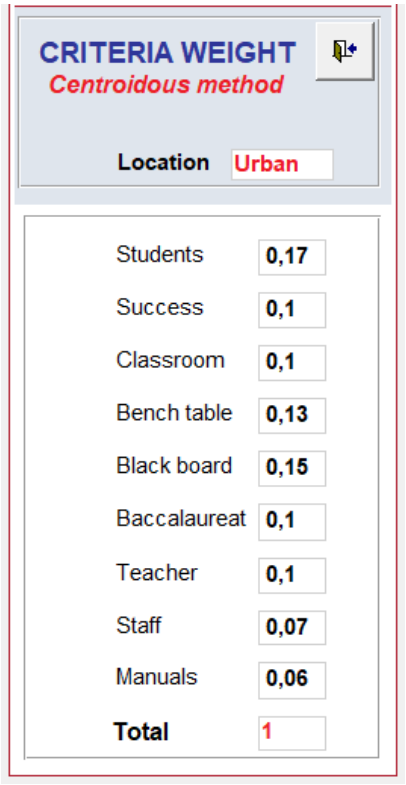
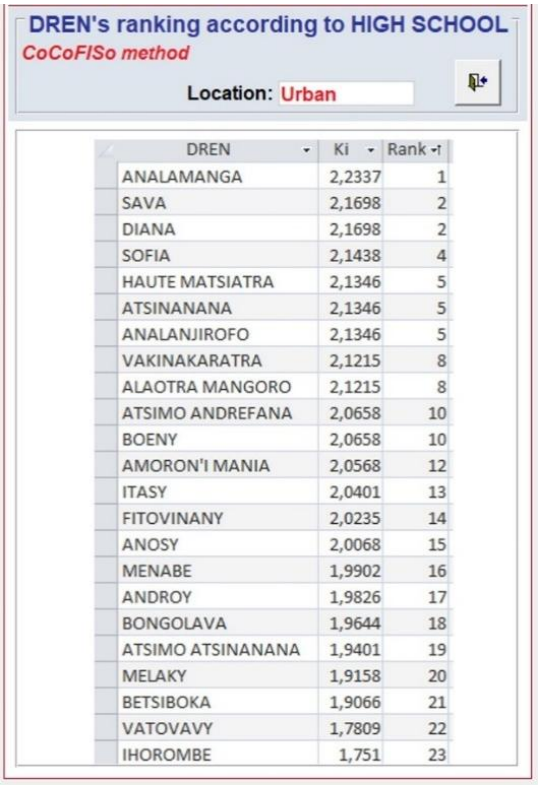


Fig. 13. Urban criteria weight



DREN	Ki	Rank
ANALAMANGA	2,2337	1
SAVA	2,1698	2
DIANA	2,1698	2
SOFIA	2,1438	4
HAUTE MATSIATRA	2,1346	5
ATSINANANA	2,1346	5
ANALANJIROFO	2,1346	5
VAKINAKARATRA	2,1215	8
ALAOTRA MANGORO	2,1215	8
ATSIMO ANDREFANA	2,0658	10
BOENY	2,0658	10
AMORON'I MANIA	2,0568	12
ITASY	2,0401	13
FITOVINANY	2,0235	14
ANOSY	2,0068	15
MENABE	1,9902	16
ANDROY	1,9826	17
BONGOLAVA	1,9644	18
ATSIMO ATSINANANA	1,9401	19
MELAKY	1,9158	20
BETSIBOKA	1,9066	21
VATOVAVY	1,7809	22
IHOROMBE	1,751	23

Fig. 14. Urban DREN's ranking

It would be enlightening to examine how the CoCoFISo method had ranked these DRENs. As with all multi-criteria decision-making methods, the initial weighting of the criteria is of great importance in the ranking process. Subsequently, the value of each criterion also plays a pivotal role. To illustrate this procedure, Figure 15 below shows the variation in the values of the first three criteria, which have been assigned higher weights than the others. To simplify the presentation, we have selected the normalised matrix obtained using Eq.(7) of the CoCoFISo method. In this illustration, the DRENs are ordered from first to last. It has been observed that the DRENs with higher criterion values on the three criteria (students, blackboard and bench table), whose weights are significant, were ranked higher than the others.

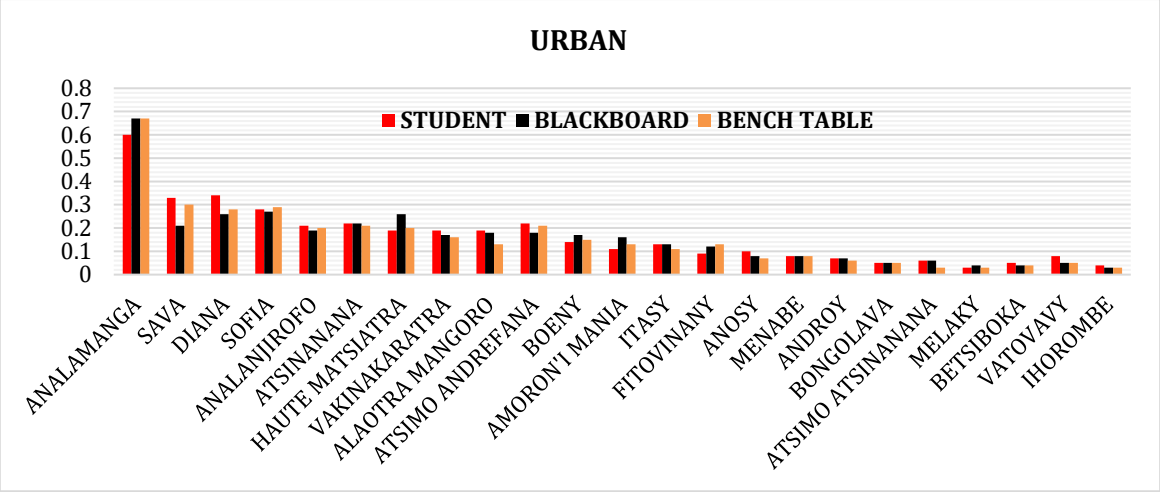


Fig. 15. Urban area: variation in the values of the first three key criteria

In fact, the DRENs have been ranked according to the situation of public high schools in urban area. Let's see how this ranking varies in rural areas.

4.3.2. Criteria weight and ranking of DRENs by public high schools in rural location

In accordance with the performance matrix for the Rural area, as illustrated in Figure 11, the MADREN software calculated the weight of the criteria and the rank of the DRENs. The Centroidous method algorithm revealed that the most important criteria are the number of students enrolled, the number of blackboards and the number of seats on the bench table. In this instance, the success rate of students in the examinations for promotion to higher classes is positioned fourth among the criteria. However, other criteria, including the number of classrooms, the success rate of students in the Baccalaureate examinations, the student-teacher ratio and the number of manuals supplied by the State, are of equal importance. Conversely, the ratio of students to administrative staff was identified as the least important criterion. In terms of quantity, the criteria are assigned weights ranging from 0.17 to 0.15, 0.13 to 0.10, 0.09, 0.08.

In accordance with the aforementioned criteria weight and the circumstances pertaining to public high schools in Rural areas, MADREN software will apply the CoCoFISo method for the purpose of ranking the DRENs. The Analamanga DREN has consistently retained its position as the leading DREN. In contrast, the remaining DRENs observed fluctuations in their rankings, either ascending or descending. On this classification, the following DRENs are ranked between the second and nineteenth places: Haute Matsiatra DREN, Vakinakaratra DREN, Alaotra Mangoro DREN, Sofia DREN, Analanjirofo DREN, Amoron'i Mania DREN, Atsinanana DREN, Atsimo Andrefana DREN, Sava DREN, Bongolava DREN, Atsimo Atsinanana DREN, Itasy DREN, Fitovinany DREN, Boeny DREN, Anosy DREN, Diana DREN, Vatovavy DREN and Androy DREN. On the other hand, the Menabe DREN and the Betsiboka DREN are the next highest-ranking DRENs, both occupying the twentieth position. Consequently, the Ihorombe DREN and the Melaky DREN are ranked twenty-second and twenty-third, respectively, according to the CoCoFISo method. The following figures present the MADREN result extract, which illustrates the result for the Rural zone. Figure 16 depicts the weights of the criteria according to the Centroidous method, while Figure 17 details the rank of the DRENs according to the CoCoFISo method.

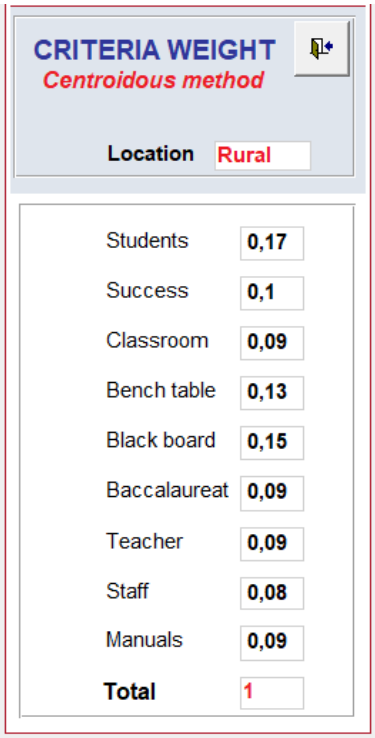
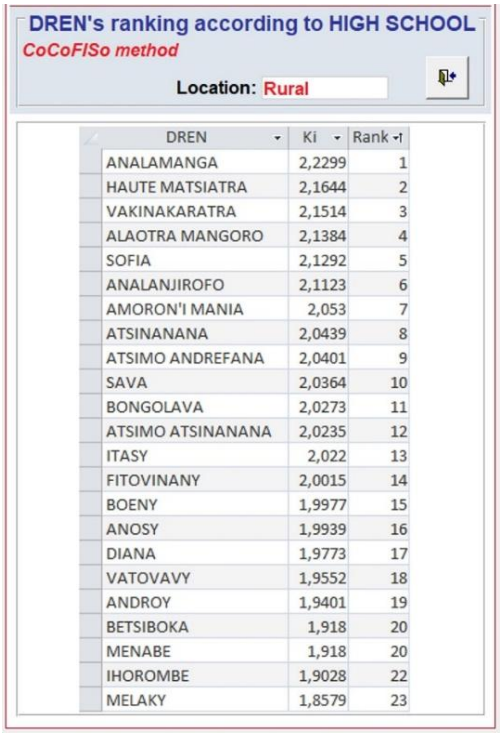


Fig. 16. Rural criteria weight



DREN	Ki	Rank
ANALAMANGA	2,2299	1
HAUTE MATSIATRA	2,1644	2
VAKINAKARATRA	2,1514	3
ALAOTRA MANGORO	2,1384	4
SOFIA	2,1292	5
ANALANJIROFO	2,1123	6
AMORON'I MANIA	2,053	7
ATSINANANA	2,0439	8
ATSIMO ANDREFANA	2,0401	9
SAVA	2,0364	10
BONGOLAVA	2,0273	11
ATSIMO ATSINANANA	2,0235	12
ITASY	2,022	13
FITOVINANY	2,0015	14
BOENY	1,9977	15
ANOSY	1,9939	16
DIANA	1,9773	17
VATOVAVY	1,9552	18
ANDROY	1,9401	19
BETSIBOKA	1,918	20
MENABE	1,918	20
IHOROMBE	1,9028	22
MELAKY	1,8579	23

Fig. 17. Rural DREN's ranking

Now, we will analyse the ranking of the DREN by the CoCoFISo method. To achieve this, the three criteria that are of greater importance will be considered, and the situation of the public high schools with regard to these three criteria will be compared. To facilitate the presentation of the graph, the normalised matrix calculated by the CoCoFISo method using Eq.(7) can be taken into account. So, Figure 18 below illustrates the disparity in the status of public high schools in Rural area, as determined by three key criteria (Student, blackboard, bench table). It has been observed that as long as these three criteria remain a priority for high schools, the DREN is in a more advantageous position. The illustration presents a ranking of the DRENs, with the most beneficial at the top and the least beneficial at the bottom. It is therefore evident that Analamanga DREN occupies a distinct and advantageous position, exhibiting notable superiority in all three criteria when compared to the other DRENs. Conversely, Melaky DREN is situated at the lowest echelon, displaying the most deficient performance across all three criteria.

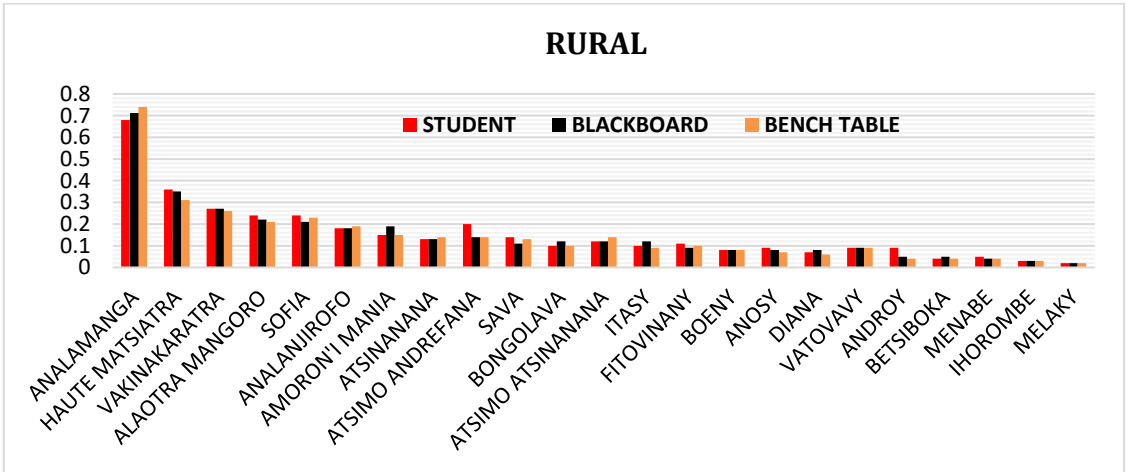


Fig. 18. Rural area: variation in the values of the first three key criteria

The outcome of the second location of public high schools in Madagascar, situated in Rural areas, was presented. This signifies the accessibility of the DREN evaluation for both types of location. Consequently, we can synthesise the results on the basis of the overall situation of public high schools in order to evaluate the DREN as a whole.

4.3.3. Criteria weight and ranking of DRENs by public high schools in all location

The results presented in this section are based on an analysis of the overall situation of public high schools in Urban and Rural areas. Figure 12 illustrates the performance matrix used by the MADREN system to calculate these results. As previously mentioned, the first result is the classification of criteria using the Centroidous method, followed by the ranking of DRENs using the CoCoFISo method.

In light of the outcomes yielded by the Centroidous method's deployment in MADREN decision support system, the criteria were categorised into six distinct levels of significance. The number of registered students was accorded the highest priority, with a weighting of 0.18. Subsequently, two further criteria were accorded the second priority status, namely the number of places available on the benches table and the number of blackboards, each assigned a weighting of 0.14. The third priority was then assigned to three criteria: the success rate of students in the promotion examinations, the number of classrooms and the success rate of students in the Baccalaureate examinations. These three criteria were assigned a weighting of 0.10. Accordingly, the fourth, fifth and sixth importance were attributed to the criteria student teacher ratio, student administrative staff ratio and the number of manuals supplied by the State to the high schools, with weights of 0.09, 0.08 and 0.07 respectively. MADREN thus accorded priority to these criteria using the Centroidous method.

In MADREN decision support system, the DRENs will be classified in accordance with the assigned weights of the criteria and the comprehensive performance matrix of public high schools. It is important to note that this classification represents the overall situation of public high schools in both urban and rural location. The results of the ranking indicate that the Analamanga DREN remained in the leading position. The Haute Matsiatra DREN was placed second. Two DRENs were then ranked third, including the Vakinakaratra DREN and the Sofia DREN. Consequently, the following DRENs were ranked from fifth to eleventh: the Alaotra Mangoro DREN, the Sava DREN, the Analanjirofo DREN, the Atsinanana DREN, the Diana DREN, the Amoron'i Mania DREN, the Atsimo Andrefana DREN. On the other hand, Boeny DREN and Itasy DREN are concurrently positioned at the twelfth rank. Subsequently, the DRENs of Fitovinany and Bongolava were ranked fourteenth and fifteenth, respectively. The DRENs of Atsimo Atsinanana and Anosy were ranked sixteenth, while Vatovavy DREN, Androy DREN and Menabe DREN were ranked eighteenth, nineteenth and twentieth, respectively. Betsiboka DREN and Ihorombe DREN were ranked twenty-first and penultimate, respectively. Finally, Melaky DREN was ranked twenty-third.

The results of the MADREN study are presented in the screen extract below. Figure 19 depicts the weights of the criteria according to the Centroidous method, while Figure 20 illustrates the ranks of the DRENs according to the CoCoFISo method.

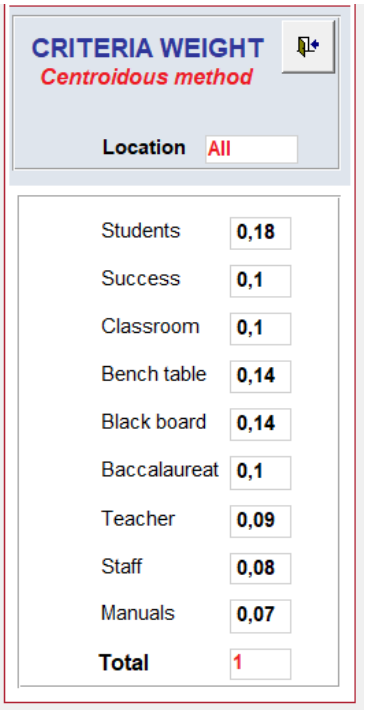
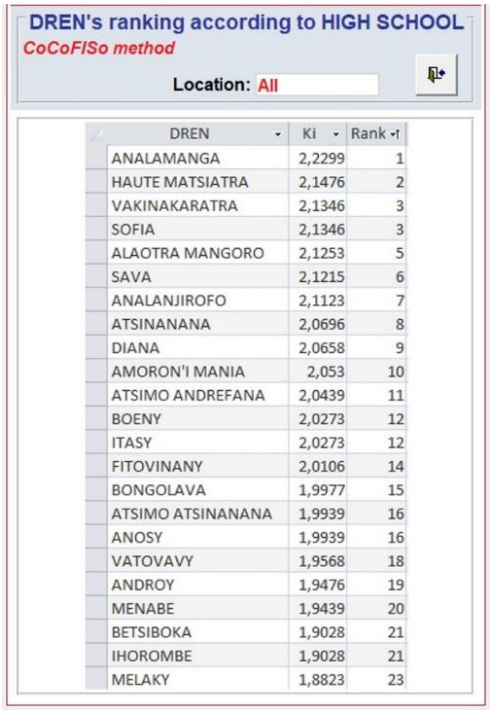


Fig. 19. All criteria weight



DREN	Ki	Rank
ANALAMANGA	2,2299	1
HAUTE MATSIATRA	2,1476	2
VAKINAKARATRA	2,1346	3
SOFIA	2,1346	3
ALAOTRA MANGORO	2,1253	5
SAVA	2,1215	6
ANALANJIROFO	2,1123	7
ATSINANANA	2,0696	8
DIANA	2,0658	9
AMORON'I MANIA	2,053	10
ATSIMO ANDREFANA	2,0439	11
BOENY	2,0273	12
ITASY	2,0273	12
FITOVINANY	2,0106	14
BONGOLAVA	1,9977	15
ATSIMO ATSINANANA	1,9939	16
ANOSY	1,9939	16
VATOVAVY	1,9568	18
ANDROY	1,9476	19
MENABE	1,9439	20
BETSIBOKA	1,9028	21
IHOROMBE	1,9028	21
MELAKY	1,8823	23

Fig. 20. All DREN's ranking

The application of the CoCoFISo method in MADREN has yielded an overall ranking of the DRENs that is consistent with the implementation of multi-criteria decision-making methods. The fundamental concept of these methods is based on the consideration of criteria according to their relative importance. The values of the criteria for each alternative must then be taken into account. Consequently, if an alternative has significant values for these criteria, it could be positioned more favourably than the others. In this case of DRENs evaluation in all location, the three most essential criteria are the number of students enrolled, the number of blackboards and the number of places available on the bench tables. It can be reasonably deduced that DRENs which have attained significant values in these three criteria will be at an advantage over those which have not. To verify this situation, we considered the normalised matrix calculated using the CoCoFISo method, with Eq.(7) employed to maintain a standard value for each DREN. As illustrated in Figure 21, DRENs with significant values for all three priority criteria are ranked higher. This is why the Analamanga DREN is ranked first, followed by the other DRENs. However, the priorities of the other criteria must also be taken into account in addition to those of the three aforementioned criteria. But in this example, just the three criteria have been taken into account.

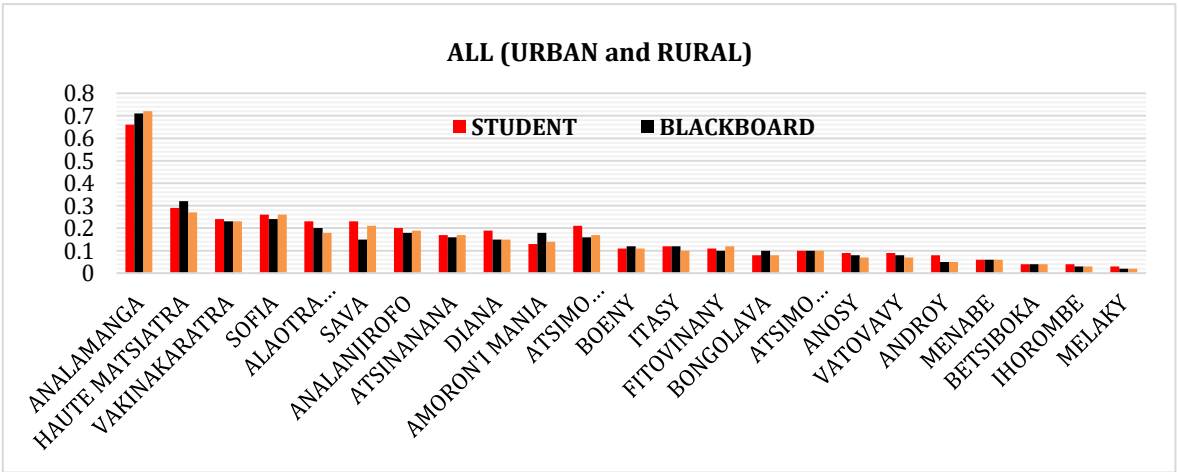


Fig. 21. All area: variation in the values of the first three key criteria

Depending on the location of the public high schools, three results are presented in this study. It is crucial to examine these three findings in greater detail. The subsequent section will be dedicated to this topic and to the conclusion of our study, with the aim of providing a comprehensive overview.

4.4. Results Analysis

In light of the preceding result, which provides a comprehensive classification of the DREN and the distinction of location according to the situation of the public high schools. We aim to assist decision-makers in comprehending the rationale behind this classification thereby facilitating their decision-making processes. It is important to note that three groups of criteria were selected for the classification of these DRENs. These include the availability of human and material resources, as well as the results of student admissions to examinations. The number of students enrolled, the ratio of student teachers and the ratio of student administrative staff represent human resources criteria. In contrast, material resource criteria include the number of classrooms, the number of places on desks, the number of blackboards and the number of manuals. The two criteria, the success rate of students in the promotion exams and the success rate of students in the national baccalaureate exam, are present in the type of admission to exams.

After using the Centroidous method to assess the importance of these criteria, and by adding up the weight of all the criteria for each category, we derived the result of the importance of the group of criteria. Thus, for all location the availability of material resources has a weight of 0.45, the availability of human resources has a weight of 0.35 and admission to examinations has a weight of 0.20. For Urban location the availability of material resources has a weight of 0.44, the availability of human resources has a weight of 0.36 and admission to examinations has a weight of 0.20. For Rural location the availability of material resources has a weight of 0.46, the availability of human resources has a weight of 0.34 and admission to examinations has a weight of 0.20. The following Table 4 describes this situation.

Table 4
Criteria group hierarchy

Location	Material resources	Human resources	Exam admission
ALL	0.45	0.35	0.20
URBAN	0.44	0.36	0.20
RURAL	0.46	0.34	0.20

Whatever the location, the classification of criteria group facilitated an understanding of the pivotal role played by infrastructure (classrooms) and essential equipment (blackboards, benches tables, manuals) in ensuring the smooth functioning of the educational process. In addition to these resources, the effective functioning of education also depends on the availability of human resources, including students, teachers and the administrative team. Consequently, access to these two types of resources will have an influence on whether students are admitted to examinations. The Centroidous method selected for this study demonstrated a strong performance against these criteria.

In order to facilitate a more nuanced comprehension of the circumstances pertaining to each DREN in relation to the various criteria, we have incorporated the percentage of each value in comparison to Madagascar as a whole, irrespective of location. Furthermore, we have ordered the DRENs according to their ranking derived from the CoCoFISo method. This approach enables a more straightforward interpretation of the specific circumstances of each DREN.

To illustrate, Analamanga DREN (03DREN) is the most highly-ranked of all the locations. With regard to the criteria that comprise the types of human and material resources, Analamanga DREN is generally valued at approximately 20% in comparison to Madagascar as a whole. In comparison to

the other DRENs, this rate of resources is notably high. When Haute Matsiatra DREN (15DREN) is taken into account, which occupies second place, the rate of its resources varies from 7% to 8%. There is a considerable discrepancy between these first two DRENs in terms of the percentage of resources. Furthermore, as the ranking of the DRENs decreases, the rate of these resources also decreases. From the twelfth position, the rate of resources reaches a maximum of 3.9%. This suggests that the DRENs occupying positions above twelfth have relatively limited resources. For instance, Ihorombe DREN (16DREN) and Melaky DREN (18DREN), which were ranked in the bottom two, had a percentage of resources ranging from 1.1% to 0.3%. Table 5 below provides details of the percentage of resources of each DREN in relation to Madagascar as a whole.

Table 5
Percentage of overall resource availability in all location

			Material resources				Human resources		
Rank	DREN		Class	Bench	Board	Manual	Student	Teacher	Staff
1	Analamanga	03DREN	23.2%	20.4%	19.6%	25.7%	17.5%	20.0%	25.9%
2	Haute Matsiatra	15DREN	8.3%	7.6%	8.9%	7.0%	7.8%	8.0%	6.8%
3	Sofia	21DREN	7.0%	7.2%	6.6%	5.9%	7.0%	7.4%	6.1%
3	Vakinakaratra	22DREN	7.0%	6.4%	6.5%	7.7%	6.4%	6.5%	5.1%
5	Alaotra Mangoro	01DREN	5.5%	5.2%	5.7%	7.9%	6.0%	5.5%	5.5%
6	Sava	20DREN	4.4%	5.8%	4.3%	2.4%	6.0%	4.0%	2.2%
7	Analanjirofo	04DREN	4.1%	5.5%	5.1%	3.9%	5.3%	4.4%	4.0%
8	Atsinanana	09DREN	3.9%	4.8%	4.5%	9.1%	4.6%	4.5%	6.0%
9	Diana	13DREN	5.3%	4.3%	4.2%	3.1%	5.0%	4.1%	3.1%
10	Amoron'i Mania	02DREN	4.2%	4.0%	5.0%	4.5%	3.6%	4.2%	3.7%
11	Atsimo Andrefana	07DREN	4.0%	4.8%	4.4%	3.0%	5.7%	6.8%	7.8%
12	Boeny	11DREN	3.9%	3.2%	3.3%	3.8%	2.9%	2.8%	3.5%
13	Itasy	17DREN	3.6%	2.9%	3.5%	3.3%	3.1%	3.6%	2.6%
14	Fitovinany	14DREN	2.5%	3.2%	2.8%	2.6%	2.8%	2.9%	2.6%
15	Bongolava	12DREN	3.3%	2.2%	2.7%	1.7%	2.1%	2.0%	1.4%
16	Anosy	06DREN	2.3%	2.1%	2.2%	2.4%	2.5%	2.4%	2.6%
16	Atsimo Atsinanana	08DREN	2.0%	2.8%	2.8%	1.4%	2.5%	2.5%	2.2%
18	Vatovavy	23DREN	1.5%	2.0%	2.1%	0.3%	2.5%	2.3%	2.4%
19	Androy	05DREN	0.8%	1.4%	1.5%	1.1%	2.2%	1.6%	1.7%
20	Menabe	19DREN	1.3%	1.7%	1.6%	1.1%	1.7%	1.8%	2.3%
21	Betsiboka	10DREN	0.7%	1.1%	1.2%	0.4%	1.1%	1.2%	1.0%
21	Ihorombe	16DREN	0.6%	0.9%	0.8%	0.7%	1.0%	1.0%	0.7%
23	Melaky	18DREN	0.3%	0.7%	0.7%	1.1%	0.7%	0.6%	0.8%
Madagascar			100%	100%	100%	100%	100%	100%	100%

The resources available to the public high in all location under the responsibility of the DREN are presented in the preceding table. Nevertheless, it is enlightening to obtain an overview of those material and human resources. The criteria of classrooms, bench tables, blackboards and manuals were considered by calculating the average percentage of material resources. Similarly, the students, teachers and administrative staff criteria were taken into account to obtain the percentage average of human resources. In examining this strategy, we have acknowledged the mean proportion of each resource type. It is frequently observed that resources tend to decrease from the top to the bottom of the list. The trend in the mean percentage of material resources compared with human resources is illustrated in Figure 22 below.

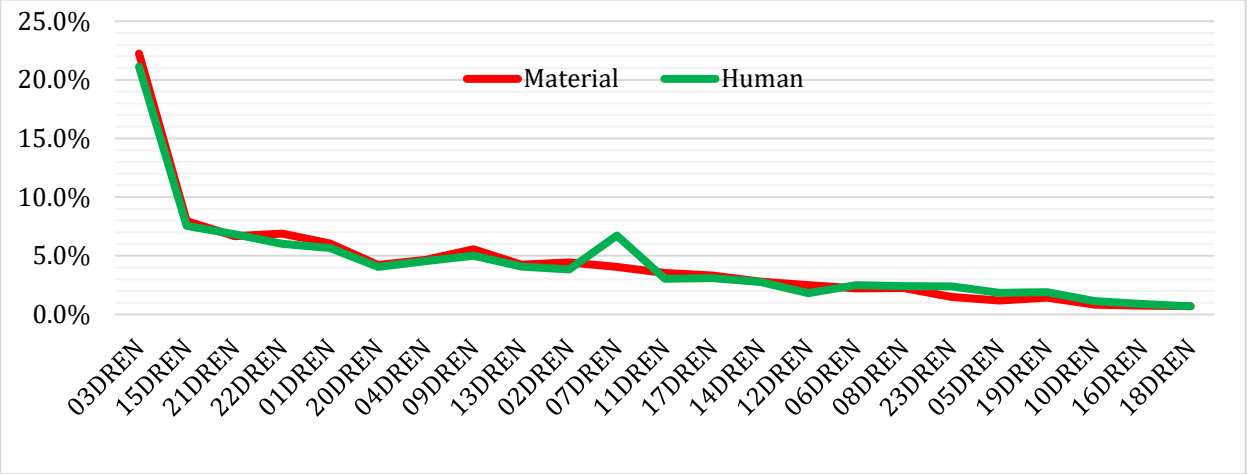


Fig. 22. All location: average percentage of resources

However, with regard to these resources, each DREN has its own situation for admitting students to examinations. Furthermore, the success rate of students in the promotion examinations and the success rate of students in the national Baccalaureate examination were also considered. The objective was to analyse the mean rate at which students were admitted to examinations. The average pass rate was found to fluctuate between 59.10% and 86.10%. Overall, the DRENs demonstrated satisfactory results with a variable trend. For instance, the Analamanga DREN (03DREN) ranked first with an average pass rate of 71.70%, while the Melaky DREN (18DREN), which ranked last, exhibited an optimized pass rate of 86.10%. Figure 23 below shows the trend in the average pass rate of students in examinations where DRENs are ranked from first to last according to CoCoFISo.

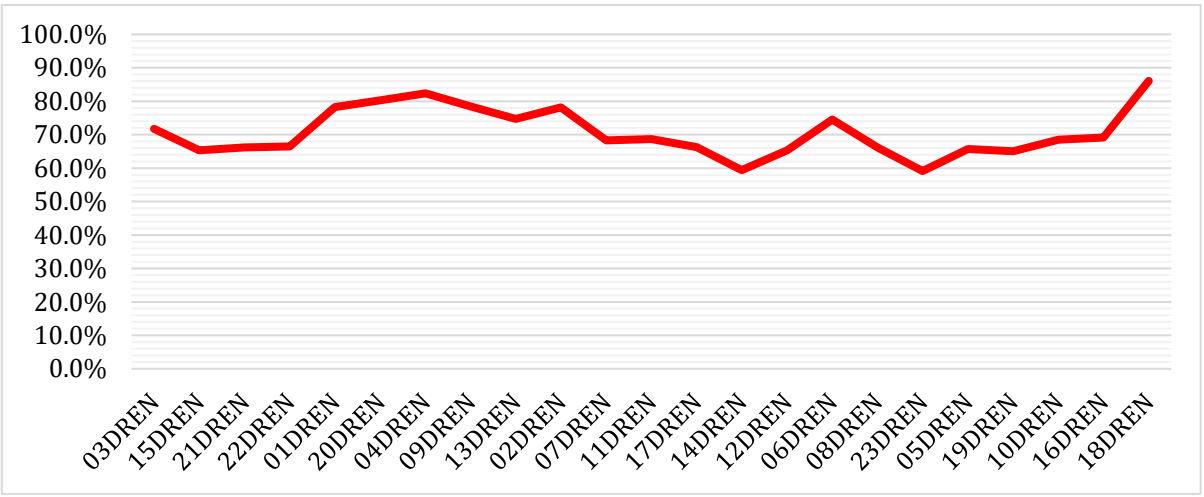


Fig. 23. All location: average admission rate to examinations

Following an examination of the overall assessment of the DREN in relation to public high schools in Madagascar, an assessment was also carried out according to their Urban and Rural location. This was done with the aim of examining the situation of public high schools in greater depth, in order to assist decision-makers. The results demonstrated that the rankings of the DRENs vary according to their location. Table 6 below compares the rank of the DRENs by urban and rural location, based on their overall rank.

Table 6
Variation in rank of DRENs by location

	03DREN	15DREN	21DREN	22DREN	01DREN	20DREN
All	1	2	3	3	5	6
Urban	1	5	4	8	8	2
Rural	1	2	5	3	4	10
	04DREN	09DREN	13DREN	02DREN	07DREN	11DREN
All	7	8	9	10	11	12
Urban	5	5	2	12	10	10
Rural	6	8	17	7	9	15
	17DREN	14DREN	12DREN	06DREN	08DREN	23DREN
All	12	14	15	16	16	18
Urban	13	14	18	15	19	22
Rural	13	14	11	16	12	18
	05DREN	19DREN	10DREN	16DREN	18DREN	
All	19	20	21	21	23	
Urban	17	16	21	23	20	
Rural	19	20	20	22	23	

Thus, by examining this rank comparison, it was observed that the DRENs can be grouped into three categories. The first category comprises DRENs that are ranked higher in urban location and lower in rural location. For the sake of brevity, we shall refer to these as 'urban DRENs'. Ten DRENs are indicated by a white box. The second category includes DRENs that are ranked lower in urban location and higher in rural location. For the sake of simplicity, we will refer to these units as ‘rural DRENs’. A total of ten other DRENs are indicated by yellow squares for this second category. The third category comprises DRENs that have constant rankings in both zones coloured green which we call ‘similar trend’ (Table 7).

Table 7
Category of DREN according to rank

Urban	Rural	DREN
Ranked higher	Ranked lower	Urban DRENs (10)
		Analanjirofo (04DREN), Androy (05DREN), Anosy (06DREN), Atsinanana (09DREN), Boeny (11DREN), Diana (13DREN), Melaky (18DREN), Menabe (19DREN), Sava (20DREN), Sofia (21DREN)
Ranked lower	Ranked higher	Rural DRENs (10)
		Alaotra Mangoro (01DREN), Amoron’i Mania (02DREN), Atsimo Andrefana (07DREN), Atsimo Atsinanana (08DREN), Betsiboka (10DREN), Bongolava (12DREN), Haute Matsiatra (15DREN), Ihorombe (16DREN), Vakinakaratra (22DREN), Vatovavy (23DREN)
Ranked Stable		**Similar trend (3)**
		Analamanga (03DREN), Itasy (17DREN), Fitovinany (14DREN)

The internal situation of the aforementioned DRENs was examined in relation to the availability of resources. In this manner, a comparison was made of the material and human resources according to their location, with the average calculated giving to the criteria that make them up. We will therefore begin by examining the case of DRENs with an urban bias. Our observations indicate that for this first category, the material and human resources of DRENs are generally greater in urban than

in rural areas. Consequently, we can conclude that as long as the resources of the DRENs in an urban location exceed those in a rural location, the DRENs will exhibit an urban bias. Figure 24 below presents this situation.

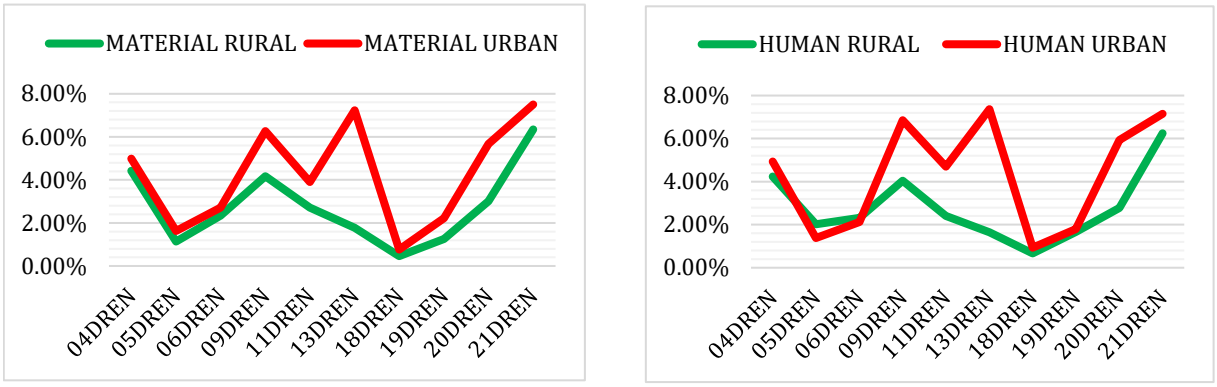


Fig. 24. DREN with urban bias: comparing average urban and rural resources

With regard to the second group of rural DRENs, it was observed that in comparison to their urban counterparts, they exhibited a contrasting pattern in terms of average material and human resources. Consequently, their resources in rural areas are considerably more substantial than those in urban areas. Therefore, it can be posited that as long as the material and human resources of the DREN are greater in rural than in urban locations, the DREN will exhibit a rural tendency. Figure 25 below illustrates this situation.

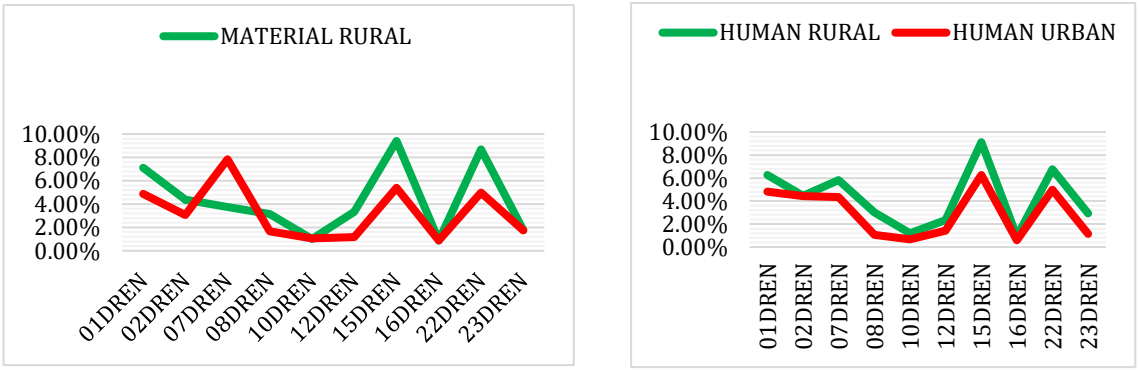


Fig. 25. DREN with rural bias: comparing average urban and rural resources

Thirdly, we have the DRENs with similar tendencies. By comparing their average material and human resources, we have taken into account that from urban to rural location these resources have very similar percentages. Consequently, we can draw a third hypothesis: if the percentages of resources are equivalent in both urban and rural locations, the DREN will belong to the similar trend category. With the exception of the Analamanga DREN, which has been grouped in this category on the basis of its equal rank in urban and rural locations. Although it has a higher average percentage of resources in the rural location than in the urban location. Consequently, it will be possible to group the Analamanga DREN among those with a rural tendency according to the characteristics of its resources. Figure 26 below shows this situation.

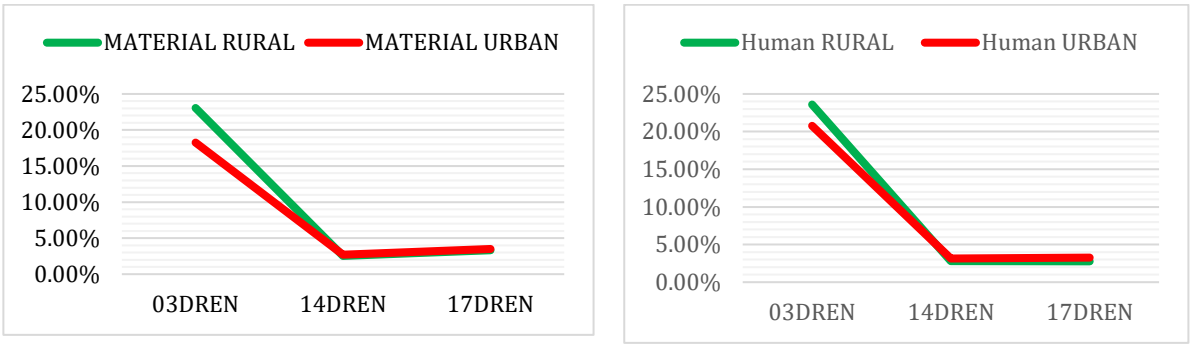


Fig. 26. DREN with rural bias: comparing average urban and rural resources

A percentage analysis of the average examination pass rate for the three groups of DRENs was also conducted, with a comparison between urban and rural locations. However, the findings revealed that the average pass rate is highly variable and does not correlate with the DREN trend. That's why we're going to move on to the last section of this research.

6 Discussion And Conclusion

This study sheds light on the information available from the Ministry of Education (MEN) in Madagascar. It suggests the use of MADREN, a multi-criteria decision support system developed on the basis of this study, to assist decision-makers at the Ministry in making decisions based on the ranking of each DREN. The two innovative multi-criteria decision-making methods developed in 2024 are of particular interest and were implemented: Centroidous to assess the importance of the criteria and CoCoFISo to rank the DRENs. The MADREN system facilitates the ranking of DRENs according to their educational sector (pre-school, primary, secondary, high), geographical location (urban, rural), and the nature of the educational institution (private, public).

In this article, a MADREN experiment was mentioned concerning all public secondary schools in Madagascar, as well as the differences between urban and rural locations. The 23 DRENs were classified according to nine important criteria that reflect the availability of resources at the public secondary schools. It is conceivable to confirm that MADREN has succeeded in its experimentation by showing that the desired results have been achieved. Centroidous was able to determine the weights of the criteria using the options proposed by MADREN. The three most significant criteria in public secondary school locations (rural, urban and overall) are the number of students, the number of blackboards and the number of benches tables. So, according to the CoCoFISo metho, generally the DRENs with significant material and human resources were ranked higher. The evaluation of these DRENs in urban and rural locations was also obtained, and it was found that some DRENs are more highly ranked in urban areas than in rural areas, and vice versa. In this way, based on these results, a disparity in the distribution of resources among the DRENs was observed. Given the resources available in Madagascar, Analamanga DREN, which ranked first in the evaluation, had 22.24% of material resources and 21.13% of human resources, while Melaky DREN, which ranked last, had only 0.71% of material resources and 0.70% of human resources. Consequently, the findings of this study may serve as a valuable resource in informing decision-making processes concerning the allocation of resources to the DRENs in addressing this situation. Remember that the introduction to this article also highlights the net enrolment rate of students at high schools, which stands at 11.95%. It is hypothesised that this rate is associated with the availability of resources at high schools. Therefore, it is imperative to implement a strategy aimed at enhancing this rate. The findings of this study underscore the crucial role it plays in informing the decision-making processes of MEN decision-makers.

In this first MADREN experiment, an investigation was conducted into the evaluation of the DREN in relation to the circumstances of public high schools in Madagascar. Centroidous was utilised as a tool for prioritising the criteria, while CoCoFISo was employed to rank the DRENs. Subsequent research will enable the use of MADREN to evaluate the DRENs according to the availability of resources at private high schools in Madagascar, with the aim of drawing comparisons with the results obtained from public high schools. However, a particularly interesting avenue for future research would be to evaluate the DRENs on the basis of the availability of resources in pre-schools, primary schools and secondary schools in both urban and rural areas, taking into account both the public and private sectors. This would provide a more comprehensive overview of the various schools.

From a methodological perspective, it is imperative for the decision-maker to establish a hierarchical structure for the criteria, a principle that underpins multi-criteria decision-making. Consequently, in its subsequent iteration, MADREN will incorporate another criteria hierarchy method, thereby facilitating this process. This will enable the manager to opt for Centroidous, a method that automatically calculates the weights of the criteria according to the performance matrix, or the new method that will be implemented and which will require manager intervention during the evaluation of the DRENs.

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Conflicts of Interest
The authors declare no conflicts of interest.

Data Availability Statement
The datasets generated during and/or analyzed during the current study is available from the corresponding author on reasonable request.

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References
[1] MEN. (2023). Annuaire statistique national 2022-2023. Ministère de l'Éducation Nationale. https://www.instat.mg/p/men-annuaire-statistique-de-leducation-2022-2023
[2] Agrawal, A., & Agarwal, R. (2022). CoCoSo: A way to Artificial Intelligence for Human Capital Selection. 2022 8th International Conference on Advanced Computing and Communication Systems (ICACCS), 1664-1667. https://doi.org/10.1109/ICACCS54159.2022.9785085
[3] Bagi, Y. S., Suyono, S., & Tomatala, M. F. (2020). Decision Support System for High Achieving Students Selection Using AHP and TOPSIS. 2020 2nd International Conference on Cybernetics and Intelligent System (ICORIS), 1-5. https://doi.org/10.1109/ICORIS50180.2020.9320823
[4] Ijadi Maghsoodi, A., Soudian, S., Martínez, L., Herrera-Viedma, E., & Zavadskas, E. K. (2020). A phase change material selection using the interval-valued target-based BWM-CoCoMULTIMOORA approach: A case-study on interior building applications. Applied Soft Computing, 95, 106508. https://doi.org/10.1016/j.asoc.2020.106508
[5] Namazi, A., & Khodabakhshi, M. (2023). A novel game theoretic method on fair economic resource allocation with multiple Criteria. International Journal of Management Science and Engineering Management, 18(3), 170-176. https://doi.org/10.1080/17509653.2022.2043196

[6] Rakotoarivelo, J. B. (2024). Multimedia Phenomena and their Impact on Schoolchildren Case Study Boeny Region. American Journal of Sciences and Engineering Research, 7(1), 73-82.
[7] Rasoanaivo, R. G., & Zaraté, P. (2023). Students' accommodation allocation: A Multicriteria Decision Support System. Facultad de Informática (UNLP). https://doi.org/10.24215/15146774e014
[8] Musani, S., & Jemain, A. A. (2013). A fuzzy MCDM approach for evaluating school performance based on linguistic information. AIP Conference Proceedings, 1557(1), 1006-1012. https://doi.org/10.1063/1.4858785
[9] Rezaur Rahman, N. S. M., Chowdhury, M. A. A., Firoze, A., & Rahman, R. M. (2019). Fusion of BWM and AHP MCDM Methods to Choose the Most Suitable Secondary School for an Individual in the Context of Bangladesh. Vietnam Journal of Computer Science, 6(3), 311-328. https://doi.org/10.1142/S2196888819500167
[10] Roszkowska, E., & Filipowicz-Chomko, M. (2020). Measuring sustainable development in the education area using multi-criteria methods: A case study. Central European Journal of Operations Research, 28(4), 1219-1241. https://doi.org/10.1007/s10100-019-00641-0
[11] Dani, D., & Agrawal, G. (2021). Evaluating the Quality of Indian School Education boards' websites using multi criteria decision making models. International Journal of Information Technology, 13(6), 1-9. https://doi.org/10.1007/s41870-018-0119-y
[12] Yüksel, F. Ş., Kayadelen, A. N., & Antmen, F. (2023). A systematic literature review on multi-criteria decision making in higher education. International Journal of Assessment Tools in Education, 10(1), Article 1. https://doi.org/10.21449/ijate.1104005
[13] Vinogradova-Zinkevič, I. (2024). Centroidous Method for Determining Objective Weights. Mathematics, 12(14), Article 14. https://doi.org/10.3390/math12142269
[14] Mohamed, M., AbdelMouty, A. M., Mohamed, K., & Smarandache, F. (2025). SuperHyperSoft-Driven Evaluation of Smart Transportation in Centroidous-Moosra: Real-World Insights for the UAV Era. Neutrosophic Sets and Systems, 78, 149-163.
[15] Rasoanaivo, R. G., Yazdani, M., Zaraté, P., & Fateh, A. (2024). Combined compromise for ideal solution (CoCoFISo): A multi-criteria decision-making based on the CoCoSo method algorithm. Expert Systems with Applications, 124079. https://doi.org/10.1016/j.eswa.2024.124079
[16] Rasoanaivo, R. G., & Tata, J. A. (2024). 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, 12(4), 18-31.
[17] Nirinarivelo, H., & Rasoanaivo, R. G. (2025). Multi-criteria evaluation of Madagascar's regions in the context of employment using the CoCoFISo method. Spectrum of Decision Making and Applications, 2(1), Article 1. https://doi.org/10.31181/sdmap21202514
[18] Karo, S. K., Prayogi, S. Y., Tampubolon, K., Limbong, R., & Tamba, R. H. (2024). Implementation of the Simple Additive Weighting (SAW) method in the decision support system for determining scholarships for students at the STIEKOM North Sumatra Education Foundation. Jurnal Multimedia Dan Teknologi Informasi (Jatilima), 6(02), Article 02.
[19] Popović, M., Savić, G., Kuzmanović, M., & Martić, M. (2020). Using Data Envelopment Analysis and Multi-Criteria Decision-Making Methods to Evaluate Teacher Performance in Higher Education. Symmetry, 12(4), Article 4. https://doi.org/10.3390/sym12040563
[20] Sari, A. P., & Oktavia, T. (2023). DSS Using MABAC, MOORA For Selection of Majors According to Students' Interests. Sinkron: Jurnal Dan Penelitian Teknik Informatika, 7(2), Article 2. https://doi.org/10.33395/sinkron.v8i2.12335
[21] Sinaga, N. A., Sugara, H., Sembiring, E. J., Manurung, M. E. M., Silaen, H., Sumantrie, P., & Siregar, V. M. M. (2022). Decision support system with MOORA method in selection of the best teachers. AIP Conference Proceedings, 2453(1), 030020. https://doi.org/10.1063/5.0094437
[22] Ziemba, P., Piwowarski, M., & Nermend, K. (2023). Software systems supporting remote education - Fuzzy assessment using a multi-criteria group decision-making method. Applied Soft Computing, 149, 110971. https://doi.org/10.1016/j.asoc.2023.110971