# Decision Support Systems for Scholarship Granting

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**Abstract.** The scholarship granting process is a necessary, but time-consuming procedure. Due to its high importance, there's a need to simplify this process. We began by contextualizing the topic, explaining what a scholarship is, as well as a Decision Support System (DSS) and Multiple Attribute Decision Making (MADM) problems and how they are relevant to this study. Then, we continue the process by analyzing several articles and reviewing the state of the art for the most predominant technologies used in this area. Subsequentially, to solve the presented problem, a proposed architecture was developed by creating a DSS with a MADM approach, based on the most relevant scoring methods previously researched and criteria mostly used in the systems of the state-of-the-art and the *Direção Geral de Ensino Superior* (DGES) yearly scholarship granting process. Finally, the authors present and discuss the results obtained from the implementation of the DSS for the scholarship granting problem.

**Keywords:** Scholarship Granting, DSS, MADM, TOPSIS, SAW, WP.

## 1 Introduction

A scholarship consists in a monthly monetary payment to support students with their teaching expenses. These can cover costs of transport, food, accommodation, materials, and tuition fees [1].

Granting a scholarship depends on several factors such as: income, household conditions, etc., established by the competent organization. After the applications are submitted, by the students, it is necessary to rectify the data, to determine if the student is in fact, eligible to earn the scholarship.

Implementing a system capable of determining which students are eligible for the scholarship grant is strongly recommended. This type of approach has the ability to assist decision-makers since the scholarship granting process can be highly demanding and time-consuming.

A Decision Support System (DSS) consists of a computer program used to support decision making. It can be used in several areas such as: health, business, or even as an organizational tool [2]. The purpose of this type of system is to provide the user with organized information about the problem in order to make the decision-making process easier [3].

The adoption of a DSS becomes a sufficient solution to the problem of student scholarship granting, because it can save a significant amount of time by processing the large amount of data required for this process while accurately identifying the students who are qualified.

However, the granting of a scholarship depends on multiple attributes, that can complicate this process.

Multiple Attribute Decision Making (MADM) consists in deducing a preferable choice (e.g., Election of a student), from the several available alternatives obtained, in a scenario where there are multiple complex attributes [4]. It's frequently utilized in ranking circumstances when preferred alternatives are required, such as the scholarship student selection procedure [5].

For the remain of the paper, a proposal of a DSS for scholarship granting is elaborated. In section 2, the technologies are contextualized and analyzed. In section 3, the proposal is described, demonstrating how the system will be developed and how it interacts with the user. In section 4, the results achieved after the implementation of the DSS are presented and thoroughly discussed. This paper ends with the conclusions obtained from the investigation and development of the DSS in the area of scholarship grant.

## 2 State of the Art

From the technologies that we researched, ranging from decision tree algorithms like C4.5 [16] to Analytical Hierarchical Process (AHP) [17] and Case Based Reasoning (CBR) [18], where some approaches even consider the utilization of Fuzzy Logic. In this literature review, we decided to focus on these 3 technologies and make a comparison between them to decide each one is the best one for this domain.

### 2.1 Simple Additive Weighting Method

Like it was said in [6], [7] and [8], the Simple Additive Weighting (SAW) method is often also known as term weighted summation method. The basic concept from SAW is to find weighted summation rating performance of each alternative on all attributes. SAW method requires a process of normalizing the decision matrix (X) to a scale which can be compared with all the rating alternatives that exist.

The SAW method steps are:

1. Determining the criteria to assess the problem
2. Determining the weight of each criterion
3. Normalizing the decision matrix based on the equations in (1) that take into consideration if a certain criterion is a benefit (first fraction) or a cost (second fraction) in this type of problem to make a normalized matrix. The normalization process takes into consideration the maximum and minimum value of each row and column.

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{Maxx_{ij}} \\ \dfrac{Min\, x_{ij}}{x_{ij}} \end{cases} \tag{1}$$

Where:

- $r_{ij}$ = normalized performance rating score
- $x_{ij}$ = attribute value of each criterion
- $Maxx_{ij}$ = the largest value of any criteria and alternative
- $Min\, x_{ij}$ = the smallest value of any criteria and alternative
- Benefit = if the greatest value is best
- Cost = if the smallest value is best

4. Determining the results, for each alternative, you need to run their respective normalized row in the normalized matrix against the weighted vector (2) for each criterion to obtain the best alternative in the decision matrix, the alternative with the highest value after performing this step for every row of the normalized matrix.

$$V_i = \sum_{j=1}^{n} w_j\, r_{ij} \tag{2}$$

Where:

- $V_i$ = rank for each alternative
- $w_j$ = weighted value of each criterion
- $r_{ij}$ = normalized performance rating value

## 2.2 Weighted Product Method

Like it was proposed in [9] and [10], Weighted Product Method (WP) is a method of decision making by multiplying to connect attribute values, where the value of each attribute must be raised first with the weight of the attribute in question. Each alternative decision is compared with the other by multiplying the number of ratios, one for each decision criterion. Each ratio is raised to the power equivalent to the relative weight of the appropriate criteria.

WP requires a normalization process because this method multiplies the results of the assessment of each attribute. The multiplication results have not been meaningful if they have not been compared with the standard values. Weights for benefit attributes function as positive ranks in the multiplication process, while cost weights function as negative ranks. The steps in calculating the WP method are:
Determining the criteria to assess the problem

1. Determining the weight of each criterion
2. Normalization or improvement of weights equation (3):

$$W_i = \frac{w_i}{\sum w_i} \quad (3)$$

Where:

- $w_i$ : initial criteria weight
- $W_i$ : final criteria weight value (after normalization)
- $i$ : data index

3. Normalization process (S) decision matrix is normalized by multiplying the attribute rating, where the attribute rating must first be raised with the attribute weight equation (4):

$$S_i = \Pi_{j=1}^{n} x_{ij}^{w_j} \quad (4)$$

Where:

- $S_i$ : alternative preferences are analogous as S vector
- $n$ : number of criteria
- $x_{ij}$ : value of criteria
- $w_i$ : criteria weight
- $i$ : alternative index
- $j$ : criteria index

4. Determining Vector Values (V) (5):

$$V_i = \frac{S_i}{\sum_i^n S} \quad (5)$$

Where:

- $V_i$ : alternative preferences are analogous as V vector
- $S$ : value of S vector
- $i$ : alternative index
- $n$ : number of S vector

5. Find the best alternative order that will be the decision

### 2.3 Technique for Order Preference by Similarity to Ideal Solution

According to [11] and [12], the Technique for Order Preference by Similarity to Ideal Solution, mostly known as TOPSIS, is a method that was developed based on the concept of searching for the best alternative that not only has the shortest distance from the positive ideal solution but also has the longest distance from the negative ideal solution in geometric point of view by using Euclidean distance. TOPSIS method ranks the alternatives based on relative nearest score priority of alternative to positive ideal solution, making it able to measure the relative performance of any decision alternatives.

The steps in calculating the TOPSIS method are as follows:

1. Determining the criteria to assess the problem
2. Determining the weight of each criterion
3. Normalized decision matrix where each element of the matrix is normalized to obtain the normalized matrix. Each normalized value can be calculated using the equation (6):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} {x_{ij}}^2}} \tag{6}$$

Where:

- $r_{ij}$ : normalized decision matrix
- $x_{ij}$ : value of the criteria $j$ on alternative $i$

4. Weighted Normalized Matrix where each element of the normalized matrix is multiplied with the respective weight of the criterion. Each weighted normalized value can be calculated using the equation (7):

$$v_i \ = \ w_j \, r_{ij} \tag{7}$$

Where:

- $v_i$ : weighted normalized decision matrix
- $w_j$ : weight for criterion $j$
- $r_{ij}$ : normalized decision matrix

5. Determining the Ideal Solution where the positive ideal solution, and negative ideal solution can be determined based on normalized weighted matrix using the equation (8) and (9):

$$A^+ = \{v_1^+, v_2^+, \dots, v_n^+\} \tag{8}$$

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\} \tag{9}$$

Where:

- $A^+$ : positive ideal solution
- $A^-$ : negative ideal solution
- $v_n^+$ : if criterion is benefit, max value found in that criterion, if criterion is cost, min value in that criterion

- $v_n^-$ : if criterion is benefit, min value found in that criterion, if criterion is cost, max value in that criterion
- $n$ : criteria index

6. Calculating Separation Measure that is a measurement of the distance of an alternative to the positive and negative ideal solution. Distance until positive ideal solution can be calculated by (10) while for the negative ideal solution is (11):

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2} \tag{10}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \tag{11}$$

Where:

- $S_i^+$ : separation measure to the positive ideal solution
- $S_i^-$ : separation measure to the negative ideal solution
- $v_{ij}$ : weighted normalized decision matrix
- $v_j^+$ : positive ideal solution
- $v_j^-$ : negative ideal solution

7. Calculating the Relative Closeness which is the closeness to the positive ideal solution. Relative closeness of the alternative $A^+$ to $A^-$ ideal solution represented by (12):

$$V_i^+ = \frac{S_i^-}{S_i^- + S_i^+} \tag{12}$$

Where:

- $V_i^+$: relative closeness to the positive ideal solution, $0 \leq V_i^+ \leq 1$
- $S_i^-$ : separation measure to the negative ideal solution
- $S_i^+$ : separation measure to the positive ideal solution

8. Sorting Preference where the best alternative is the shortest to the positive solution and the longest to the negative ideal solution so we can sort considering $V_i^+$ and the alternative with higher $V_i^+$ is the best solution.

### 2.4 Comparison

After a careful search through papers, we found 2 papers [5] and [3] that directly compared the previously mentioned methods. The distinctions between them are the normalization process for comparing all performance ratings on a common scale and the aggregation of the normalized decision matrix and weighting vector for obtaining an overall preference value for each alternative. Furthermore, using the same decision matrix and weighting vector may produce different outcomes. In the paper [3], SAW and

WP methods produce the same outcome while TOPSIS varied from those two. Paper [5] compares the three methods and concludes that TOPSIS was the worst out of the bunch since it continued to produce different results from the other two and had the highest average expected value loss. Moreover, using this last metric to distinguish the other two methods, the results prove that SAW methods is the best out of the 3 in every setting tested. Finally, the order in which the items are arranged in descending order of performance is SAW, WP, and TOPSIS.

## 3 Proposed Architecture

The DSS to be developed aims to aid the scholarship granting system in Portugal, namely, *Direção Geral de Ensino Superior* (DGES), which is the major institution responsible for university scholarships yearly. The submission process always occurs in September before a new school year.

The goal of this project and how it will differentiate from the rest of existing projects is the ability to give the users the possibility to use each scoring method mentioned in State of the Art or a combination of them, in order to solve the MADM problem, present in the scholarship granting process.

This is considered a structured problem and can be dealt either synchronously or asynchronously. Thus, the project will be supported by a python application, recurring to the *Tkinter* library as a graphical user interface (GUI) framework. To assist the decision-maker, this User Interface is straightforward and user-friendly.

### 3.1 Proposed Criteria

In order to evaluate each alternative, a set of criteria is needed. This criteria list was based on the other papers of the literature with a special attention to the aspects considered to obtain DGES scholarship. To normalize our criterions, we decided to use a scale between 0 and 1, transforming them into score value.

From an initial list of criteria, we decided to use in our proposed system:

**Degree of disability superior to 60%?** This criterion was obtained directly from the DGES formulary to obtain their scholarship and the possible answers are Yes or No. Considering that answering Yes to this question means the necessity of special care and adapted classes, we considered the following transformation into score value:

**Table 1.** Fuzzy Number for Criterion of Degree of disability superior to 60%?

| Possible Answer | Score Value |
|---|---|
| yes | 1 |
| no | 0.01 |

**University Entrance Average Grade or Average Grade considering ETCS completed:** This criterion was obtained from the state-of-the-art papers, and we think it is a valuable tool to understand a student's performance. In the case of new students entering university for the first time, this criterion accepts the university entrance average grade of the student to the university that he was able to join. In the rest of the cases, being students already in bachelor's or master's, the criterion now uses the average grade considering the ETCS completed. European Credit Transfer System credits are a numerical measure of the workload completed. One credit normally corresponds to between 25 to 30 hours of work, and 60 credits represent the workload of an academic year of study. Normally 30 credits represent a semester and 20 credits a term [13]. The higher the grade, the better it is so the transformation into crisp score takes that into consideration and we created meaningful scales to simulate the ones used normally.

**Table 2.** Fuzzy Number for Criterion of University Entrance Average Grade or Average Grade considering ETCS completed

| Possible Answer | Score Value |
|---|---|
| $17.50 \leq$ Grade $\leq 20.00$ | 1 |
| $15.00 \leq$ Grade $< 17.50$ | 0.75 |
| $12.50 \leq$ Grade $< 15.00$ | 0.50 |
| $9.50 \leq$ Grade $< 12.50$ | 0.25 |
| $0.00 \leq$ Grade $< 9.50$ | 0.01 |

**Value of movatous assets:** This criterion was obtained from DGES submission formulary to obtain their scholarship and constitutes the sum of all the credit on bank accounts (checking and savings) and other types of investments. In order to create our transformation to crisp value, we used a news article that state the ranges of the values [14].

**Table 3.** Fuzzy Number for Criterion of Value of movatous assets

| Possible Answer | Score Value |
|---|---|
| $0 \geq$ Value $\geq 10000$ | 1 |
| $10000 >$ Value $\geq 40245$ | 0.66 |
| $40245 >$ Value $\geq 100000$ | 0.33 |
| Value $> 100000$ | 0.01 |

**Per capita household income:** Total yearly income of each member and then divided by the number of members. Following Pordata's data [15] and considering that this is per capita, we adapted the ranges, so it reflected that aspect and not as extensive as the ones they use. Besides, to create our transformation to crisp value, we use the value table:

**Table 4.** Fuzzy Number for Criterion of Per capita household income

| Possible Answer | Score Value |
|---|---|
| 0 ≥ Value ≥ 5000 | 1 |
| 5000 > Value ≥ 12500 | 0.75 |
| 12500 > Value ≥ 25000 | 0.50 |
| 25000 > Value ≥ 50000 | 0.25 |
| Value > 50000 | 0.01 |

**Obtained this scholarship in previous year?** This criterion was obtained from DGES website as they show an option of automatic granting for cases if the students' household composition was not changed, or household income did not increase for more than 10% in comparison to previous year if they applied and got the scholarship. We assuming a similar criterion in our system so the possible answers are yes or no and answering yes is considered a positive aspect, so we obtain the following transformation into crisp score:

**Table 5.** Fuzzy Number for Criterion of Obtained this scholarship in previous year?

| Possible Answer | Score Value |
|---|---|
| yes | 1 |
| no | 0.01 |

### 3.2 Proposed Workflow

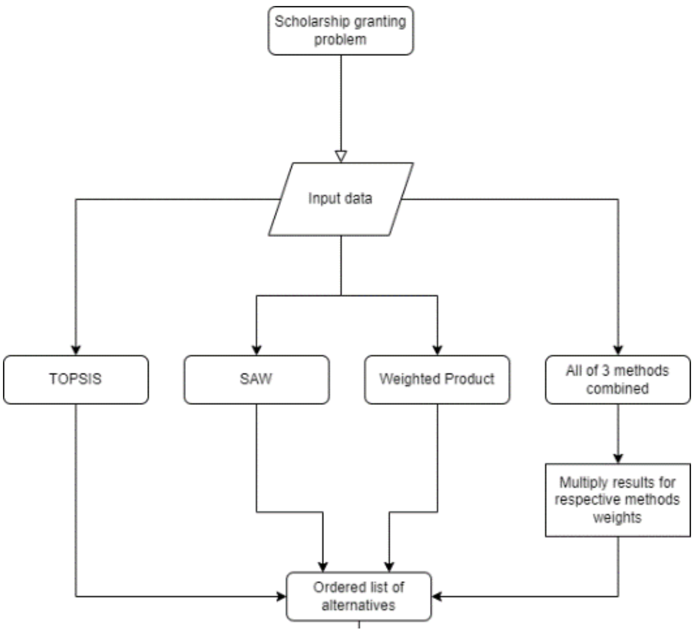


**Fig. 1.** Flowchart of the proposed system – Part 1

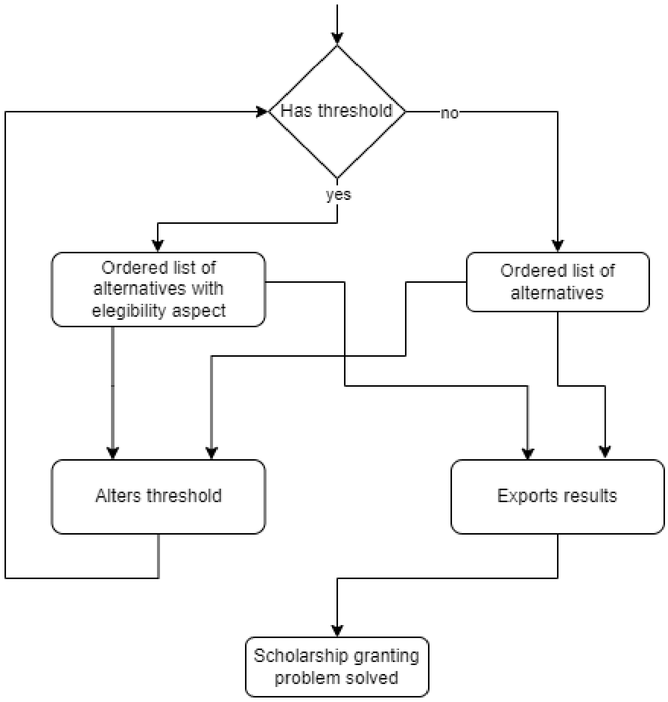


**Fig. 2.** Flowchart of the proposed system – Part 2

As mentioned in the

**Fig. 1**, the alternatives data used as input that can be inserted in the moment (synchronous) or be loaded from an external file (asynchronous). In the case of synchronous, an option will be available for the user to save the data inputted into our system about the alternatives in a file so it could be used in the future. With this input data obtained, the user needs to give weights for each criterion utilized by the system (totaling 1) and decide how they pretend to use our system, being it one of the three possible methods or a combination of them. In the case of deciding for the combination, the user needs to input the weight that should be given to each, where we offer a default value combination based on our comparison section of the state of the art. In the end, the user can optionally submit a threshold, that being the number of scholarships or score value minimum, that will be applied to the results to further facilitate the decision making, showing who is eligible for the scholarship or not.

With all this input data ready to be used, we send it to the option decided by the user and show an ordered list of the alternatives afterwards according to what was selected, that being the method selected and the existence of threshold. In **Fig. 2**, we can see that the threshold value can be added if it did not exist previously or be changed in the results GUI to help the user adjust the eligibility aspect of the results while taking into consideration the results initially shown. To finalize the process, the user can export the results into a file or just finish it, having solved the scholarship granting problem.

## 4 Results and Discussion

Since the data handled needed as input by this system is confidential and the authors do not have access to it, the authors decided to create a JSON file with fictional data to test the system and obtain results.

We used a python framework, **mcdm**[1], that already had implementations of SAW and TOPSIS method. Careful research has done through the framework documentation to understand how it works so the right normalization method was selected for each method. From this research, we found out that Multiplicative Exponential Weighting (MEW) was similar with WP, in which we used MEW method from the framework and done the needed calculations afterwards to transform it into WP method (step 4 of WP in 2.2).

Using the same alternative information (**Table 6**) and criteria information (**Table 7**) for each method, without a threshold value, and in the mixed approach using the weights of 0.45 for SAW, 0.35 for WP and 0.2 for TOPSIS that we thought were reasonable considering the comparison made in the state-of-the-art, we confirmed the state-of-the-art statement that with the same input data, the methods would give different values and results as we can see in **Table 8**.

**Table 6.** Alternative Information

| id | Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 | Criterion 5 |
|---|---|---|---|---|---|
| A1 | No | 17.5 | 50000 | 30000 | Yes |
| A2 | No | 18.7 | 70000 | 80000 | Yes |
| A3 | No | 11.2 | 20000 | 8000 | Yes |
| A4 | No | 16.4 | 3000 | 4000 | No |
| A5 | Yes | 13.5 | 3000 | 90000 | No |

**Table 7.** Criteria information

| id | Weight | IsBenefit |
|---|---|---|
| C1 | 0.30 | True |
| C2 | 0.10 | True |
| C3 | 0.15 | False |
| C4 | 0.15 | False |
| C5 | 0.30 | True |

[1] https://pypi.org/project/mcdm/#ref4

**Table 8.** Results of GDSS system

| SAW | | TOPSIS | | WP | | Mixed | |
|---|---|---|---|---|---|---|---|
| A3 | 0.540 | A5 | 0.634 | A3 | 0.200 | A3 | 0.420 |
| A5 | 0.505 | A2 | 0.426 | A1 | 0.173 | A1 | 0.379 |
| A1 | 0.490 | A1 | 0.410 | A5 | 0.117 | A5 | 0.369 |
| A2 | 0.454 | A3 | 0.360 | A2 | 0.110 | A2 | 0.332 |
| A4 | 0.381 | A4 | 0.074 | A4 | 0.061 | A4 | 0.269 |

For these results to be possible, we had to change the score values from 0 to 0.01 because of WP, since we had yes or no questions, it would give 0 as a result most of the times since it involves multiplication, not the best suited for our proposed criteria initially. With the change on the score value, the results show that TOPSIS method ranks the alternatives completely differently from the rest, confirming the results of the papers studied in the discussion of the state-of-the-art. WP and SAW rank similarly, with SAW better before the score value change, but with this change, the mixed approach, that gives more weight to SAW than WP, we see that the ranking results are the same as WP, leading us to believe that WP is the best method for our design of the problem, out of the 3 studied in the state-of-the art. The mixed approach at the end, served as a control to discussion of the result. The mixed approach came from Random Forest concept and the curiosity of the author in seeing what would happen when the results of all 3 methods were combined.

## 5 Conclusions

In the scholarship granting process, the required time to solve the problem is high and demanding. This way, our designed application intends to solve the scholarship granting problem by accelerating the procedure and aiding the decision-maker.

In this paper, we began by contextualizing the problem, where we explained what a scholarship entails, as well as the DSS and the MADM problem, and how they are related.

After the contextualization, several papers were analyzed in order to describe and compare the researched technologies and methods.

In a later stage, a proposal was elaborated where the proposed criteria and workflow were defined and explained.

Finally, the previously described criteria and workflow were followed in the implementation of a DSS for the scholarship awarding problem. The devised approach proved to be useful, and it may certainly improve the decision-making process in a scenario such as this one.

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