

Use of AHP and Promethee for Research Project Portfolio Selection

Heloise Acco Tives Leão[1(✉)], Edna Dias Canedo[2], Pedro Henrique Teixeira Costa[2], Márcio Vinicius Okimoto[2], and Giovanni Almeida Santos[2]

[1] Department of Computer Science, Lutheran University Center of Palmas (CEULP), P.O. Box 85, Palmas, TO, Brazil
heloise.acco@gmail.com, marciobtos@gmail.com, giovannix@unb.br

[2] Department of Computer Science, University of Brasília (UnB), P.O. Box 4466, Brasília, DF 70910-900, Brazil
ednacanedo@unb.br, phtcosta@gmail.com

Abstract. Multiple Criteria Decision Analysis (MCDA) methods are increasingly used in complex decision problems that involves several decision parameters, often faced by the decision makers involved in the planning process. The need to rank projects submitted to research scholarship programs in higher education institutions is a common practice that can be supported by the application of the AHP and Promethee II methods. This work applies the use of these methods in the selection of research scholarship projects, based on a case study, carried out with data from the Call for Proposals of the Institutional Program for Scientific Initiation (ProIC/PIBIC) - 2017/2018 of the University of Brasília (UnB). The methodology involved the construction of the model with multiple criteria in order to facilitate the decision making with the formalization and definition of the decision alternatives for the ranking of the projects submitted by the teachers. The results showed a classification adhering to the items considered relevant by the Institution in the classification of projects. Although the constructed model has been applied in the context of a single institution, it can be used by other institutions of higher education, since the ranking criteria defined by the Bodies of Fomentation are similar.

Keywords: Analytic Hierarchy Process · Promethee II · Multiple Criteria Decision Analysis · Ranking project

1 Introduction

Decision makers, whether they are individuals or committees, have difficulty processing and systematically evaluating relevant information. This assessment process involves confronting trade-offs between the alternatives under consideration. Each decision maker will need to prioritize what matters most. If more than one individual is involved, the priorities of involved decision makers can, and

© Springer Nature Switzerland AG 2019
S. Misra et al. (Eds.): ICCSA 2019, LNCS 11619, pp. 504–517, 2019.
https://doi.org/10.1007/978-3-030-24289-3_37

frequently do, conflict, increasing the difficulty and complexity of the decision-making process. Despite this complexity, decisions are made: even sticking with status quo is itself a decision. Relying on informal processes or judgments can lead to sub-optimal decisions. Without a formal process to evaluate alternatives and priorities, there may be inconsistency, variability, or a lack of predictability on a particular factor's or criterion's importance in the decision. The decision makers' credibility and potentially legitimacy may come into question, and this is especially true for accountability on a decision made by a university if there is a lack of transparency about how a decision was made [23].

The decision-making process can be improved by working with decision makers and stakeholders providing support and structure to the process. Using structured, explicit approaches to decisions involving multiple criteria can improve the quality of decision making and a set of techniques, known under the collective heading multiple criteria decision analysis (MCDA), are useful for this purpose. This set of techniques provides clarity on which criteria are relevant, the importance attached to each, and how to use this information in a framework for assessing the available alternatives. By doing so, they can help increase the consistency, transparency, and legitimacy of decisions [23].

Each year, the University of Brasília (UnB) publishes three notices exclusively for the selection of undergraduate students to participate in research projects, such as: Program of Scientific Initiation (PIBIC), Program of Scientific Initiation in Technological Development and Innovation (PIBITI) and Program of Scientific Initiation in Affirmative Actions (PIBIC-AF), the latter aimed at students who are beneficiaries of social inclusion policies. The selection of projects and scholarship holders is currently performed by the sum of the scores obtained in the criteria defined in the selection document. In these criteria there is a maximum score to be accepted, but there is no weight assignment to the criteria.

The use of Multiple Criteria Decision Analysis (MCDA) is an efficient and effective tool for integrating stakeholders' values and preferences into multi-criteria scenarios and provides support for the complex decision-making process [11]. In the definition of rankings and assistance in the selection of candidates, the use of MCDA is frequent, since it can help in the structuring of the problem, in the evaluation of the candidates and in the selection itself, guaranteeing the consideration of all the criteria established by those involved in the decision [17].

This paper will present the literature review on the use of MCDA methods to classify projects, research grants or the like, as well as the results of the study of the application of the AHP and PROMETHEE II methods in a real scenario.

This paper is organized as follows. Section 2 presents the state of the art related to decision-making process. Section 3 presents the research methodology adopted to develop this work. In the Sect. 4, the results and discussion are detailed. The conclusions and future work are presented in Sect. 5.

2 Background

The decision-making process has undergone changes over the last decades. The criteria definition is a phase of great importance in the decision-making process,

since it is through the defined criteria that the decision-making model will be created, thus allowing the establishment of preferential relations between existing alternatives [3]. With this, it is perceived that the quality of the construction of this model is fundamental for the quality of the support to the decision, as well as to provide greater effectiveness to the decision making process and greater chance of reaching the defined objectives.

Multiple Criteria Decision Analysis (MCDA) has been an area of rapid growth in operations research and management science during the last decades [8]. It is noticed that the MCDA methods aim to improve the degree of conformity and coherence between the evolution of a decision-making process, the value systems and the objectives involved in this process [9].

To achieve these objectives, concepts, tools and procedures must be defined. Trying to help open the way between ambiguities, uncertainties, and the abundance of bifurcations in the decision-making process. Multicriteria Decision Analysis is organized into three main phases [2] (Fig. 1):

1. Identification and structuring of the problem: before the analysis begins, stakeholders, including facilitators and technical analysts, need to develop a common understanding of the problem, the decisions that must be made, and the criteria by which those decisions will be judged and evaluated.
2. Construction and use of the model: formal models are developed so that the alternative policies or actions under analysis can be compared systematically and transparently.
3. Development of action plans: the analysis does not "solve" the decision problem. This requires the implementation of results, this means transforming the analysis made into specific action plans. With this, the use of MCDA processes must support the implementation and use of the method.

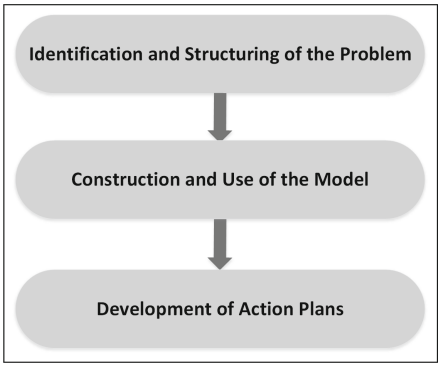

Fig. 1. Phases of Multicriteria Decision Analysis

In the specific case of the ranking and selection of projects, the main objective is to select a set of projects from all available projects considering only their

individual characteristics and the constraints imposed by the system [14]. Considering this restriction, it was identified from the analysis of the case studies that the use of MCDA with the classification (ranking) methods AHP [16], is used to support the solution of similar problems in the literature.

2.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP), was developed by [20] drawing on mathematics and psychology [9]. This method has been extensively studied and refined, with the aim of providing a means to represent hierarchically the elements involved in a process of choice [11]. Because of its simplicity, ease of use, and great flexibility, the AHP has been studied extensively and used in nearly all applications related to MCDA since its development. The integrated AHP can result in a more realistic and promising decision than a stand alone AHP. There is no doubt that AHP is one of the most popular MCDA approaches [15,20].

Basically, the AHP method consists of a structured technique to assist in making complex decisions. Instead of prescribing an optimal decision, it provides mechanisms for decision-makers to find a solution that fits their needs and helps them understand the problem. This is possible, since with the use of the method, a comprehensive and rational structure is provided to define and organize a problem and from there represent and quantify its elements, relate these elements to the general objectives and evaluate the proposed solutions [25].

It also characterizes the method of organizing decision variables into successive levels of importance, examining the interrelationship between the parties and simplifying the decision-making process. For its correct application to be performed, the AHP encompasses 5 main steps, as presented by [11,20] and [6]. These steps are (Fig. 2):

1. Define the problem and determine the type of knowledge sought.
2. Structure the decision making hierarchy and from this define the objectives through a perspective in levels. In this hierarchy the main objective is presented with criteria and subcriteria and lower levels represent the alternatives list.
3. Construct a set of comparison matrices with each pair, where each element of a higher level is used to compare the elements of the level immediately below it.
4. The hierarchical synthesis is then presented, after repeated execution of the steps until all pairwise comparisons are made.
5. Together with the presentation of the ranking resulting from the implementation of the AHP method must be provided the consistency index and the consistency rate of the application of the method.

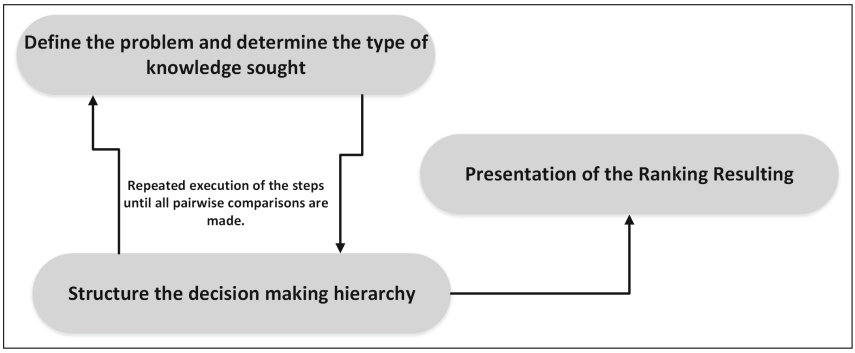

Fig. 2. Steps of Analytic Hierarchy Process

2.2 Promethee

In the 1980s, Brans and Vincke [4] presented the PROMETHEE (Preference Ranking Method for Enrichment Evaluation) methods, with the proposal to build and exploit a relationship of over-classification of values [4], clearly understood by decision-makers, adding simplicity and stability to the methods previously used [1].

Initially, were presented the methods PROMETHEE I, which provides a partial ranking of actions, and PROMETHEE II, which results in a complete classification performed through the pairwise comparison of alternatives [4]. From this, some variations of the PROMETHEE methods have been proposed to be used in different circumstances and to solve problems of ordering and application in systems hierarchy of water supply and sewage projects [5] and selection of projects from the strategic planning of a Brazilian electric sector company [14]. Among the variations of PROMETHEE, can be mentioned the PROMETHEE-III, IV, V and VI [5].

PROMETHEE II has proven to be efficient when it comes to project ranking, since it deals with the complete classification of many alternatives from the best to the worst in terms of conflicting criteria [22], calculating the positive and negative flows of preferences for each alternative. The positive flow happens when one alternative is exercising dominance in the others and the negative flow, when an alternative is dominated by the others [21].

In order to be correctly implemented, the execution of 4 steps of the method is indicated, consisting of [4]:

1. Define the preference function, which shows the preference of the decision maker for an alternative “a” to another alternative “b” in relation to a criterion;
2. Calculate the preference index, used to quantitatively compare alternatives in pairs, taking all the criteria into consideration comprehensively;
3. Construct an overcoming valued graph, where the inflows and outflows are determined by preference indexes; and
4. Present the alternatives of classification according to the result generated.

As can be seen, the central idea of PROMETHEE is the pairwise comparison of alternatives with the criteria first, one by one, then comprehensively [21], providing a deep insight into the alternatives since it takes into account the preferences and priorities of the decision maker [24].

2.3 Related Works

Haddad et al. [12] proposed an expert system to select a most suitable discrete MCDA method using an approach that analyses problem characteristics, MCDA methods characteristics, risk and uncertainty in inputs and applies sensitivity analysis to the inputs for a decisional problem. The approach provided decision makers with a suggested candidate method that delivers a robust outcome. Two MCDA methods are compared and one is recommended by calculating the minimum percentage change in criteria weights and performance measures required to alter the ranking of any two alternatives. A MCDA method was recommended based on a best compromise in minimum percentage change required in inputs to alter the ranking of alternatives.

Strategies of ranking and prioritization of projects directly influence the performance of organizations and the cost-benefit relationship of project development. The work carried out by [7] reports that due to the scarcity of funding and appropriate technologies, the ranking and selection projects of a portfolio can become a problem of the decision making process.

In this context, the work presented by [7] applies a project prioritization mechanism within a broad set of proposals, in order to identify the projects that best satisfy a set of criteria defined by decision makers. In order to carry out this rankings, MCDA techniques are applied, such as the AHP, which has been shown to be able to assist in the prioritization of projects by companies and institutions in different fields of activity.

MCDA methods are also applied in the prioritization of new Information and Communication Technology (ICT) projects. The work developed by [19] presents the application of a multicriteria analysis method and business process modeling using Business Process Modeling Notation (BPMN). In this work, the ICT department of an educational institution was used as the case study. In order to carry out the desired process, it was initially modeled the prioritization scheme of new projects of the department, to perform the survey of criteria, attribution of weights and values, divided between two evaluations: management and ICT.

The implementation of the PROMETHEE method proposed by [19] provided a general ranking of the evaluated projects, which were separated into two rankings with the management and ICT assessments in order to compare. The analysis of the obtained results allowed to conclude the validity of the MCDA methods to help in the selection and management of projects portfolio.

Morton et al. [18] present a formal model of the use of MCDA methods to guide selection of a subset of available projects, in order to maximize the resulting portfolio performance against multiple criteria. Criteria should be defined

in order to meet the availability of existing resources, as well as to meet the constraints listed by decision makers.

3 Research Methodology

The choice of the appropriate MCDA method to deal with the problem proposed in this work was based on a review of the literature on the subject. From the search term repeated in the search bases it was possible to identify, filter and select articles to compose the systematic review. The digital search libraries of the literature review were: DBLP; ACM; Scopus; IEEExplorer.

After a complete reading of the articles selected during the search process, it was possible to describe the literature review and define the methods to be used in the case study the AHP and PROMETHEE II due to several studies reporting case studies with the respective methods. With the implementation of the methods and results obtained, these were compared and discussed in order to form a proposal for the standardization of the ranking of projects and research grants at the University of Brasília (UnB).

According to the standard defined by Belton [2] to guide the phases of MCDA problems, this work, in the case study, carried out in the identification and structuring stage of the problem the tasks of: mapping the existing scenario, project objectives delimitation, stakeholder's determination, analysis of possible alternatives, uncertainty survey, external environment assessment, definition of restrictions and criteria to be used.

To support the definition of the criteria to be used in this case study was applied in the data from the call results of the Institutional Program for Scientific Initiation ProIC/PIBIC - 2017/2018 of the University of Brasília [13], with the support of WEKA software [13], the use of the AttributeSelection algorithm. This algorithm, that uses CfsSubsetEval for attribute evaluation and BestFirst for search, brought the indication of the most relevant criteria to be used in the case study.

From this it was possible to construct the model with multiple criteria, in order to facilitate the decision making with the formalization and definition of decision alternatives for the problem in question – Scientific Initiation Projects Selection at University of Brasília (UnB).

The application of the chosen methods and comparison of the results is presented in the Results and Discussion Section, where a proposal is made of a method that provides conditions to rank in a reliable and structured way, in order to improve the quality of the selection process of the program, a set of research projects among all the enrolled projects taking into account the restrictions and criteria of each notice and forming a solution that can be replicated over time, thus maintaining consistency and standard in the evaluations carried out.

3.1 Identification and Structuring of the Problem

Currently, the project selection form for the Scientific Initiation Program (PIBIC) of the University of Brasília (UnB) is carried out in the conventional way, in which the completed forms are evaluated through a web system, that is, document conferencing. This information is collected through a file extractor that includes this information.

After extraction, the information is sorted and classified manually beginning with the restrictions set forth in the notice and in the sequence the grades counting process is performed for the projects, teachers and students participating in the program selection process. Among the stakeholders involved in the implementation of this case study are:

- Directorate of Scientific Initiation of the Deanery of Research and Postgraduate Studies (DIRIC) that is responsible for formulating and managing (executing, coordinating and evaluating) the policy and scientific initiation program of UnB;
- Undergraduate students enrolled in any Institution of Higher Education;
- The faculty members of the University of Brasilia, in actual exercise and the retirees or visitors of UnB.

It was identified as an external environment and complementary to the application of the model, the research promotion institutions that sponsor the projects of Scientific Initiation and the impact, be it positive or negative, of the academic and practical application of the selected projects.

As alternatives in the process of ranking and selection of projects, all the projects that have been submitted to the notice are in a single file in spreadsheet format, with the information and the items foreseen for the classification of the projects and their teachers (mentors) and students to perform the analysis.

During the analysis of the selection process and execution of research projects by PIBIC of the UnB, several uncertainties were mapped, being the most relevant:

- Lack of financial support from research promotion institutions, which may make it unfeasible to launch calls for projects selection;
- Change in current legislation, which may bring legal and/or financial uncertainty to projects in progress;
- Specificities or not clarification of the details of the projects selection process of the UnB, which can lead to the selection of projects with merit inferior to those not selected.

According to the articles selected in the literature review, the definition of the criteria is a phase of great importance in the decision making process. Thus, in this case study, the selection process and classification of project applications was made based on the understanding of the attributes contained in the official announcement of the Institutional Program of Scientific Initiation (ProIC/PIBIC) - 2017/2018 of UnB, being:

- For the Mentor profile: total point limit - 60 points
  - Guidance experience completed: Co-guidance; Master; Doctorate.
  - Scientific, technological and/or artistic-cultural production: Articles; Book chapters; Patents; Books.
- For the scientific merit of the proposal: total point limit-40 points
  - Summary of teacher research project;
  - Student Work Plan;
  - Technical and economic feasibility (only when there is restriction).

With the application of the data mining algorithm, the criteria related to the Guidance note, Publication note, Project note, and Work Plan note were selected, and it was not necessary to include sub-criteria such as guideline sharing, master's and doctorate. The weights of the criteria followed the standard already defined in the edict. A restriction was added for project classification, which is the minimum grade that should be achieved in the criteria related to the Project note and note of the Work Plan. These two criteria must achieve at least 50% of the total possible grade in the assessment. The summary of the definition of criteria and weights used is presented in the Table 1. From the definition of the criteria, restrictions and weights for each criterion it was possible to start the construction of the proposed model.

Table 1. List of weights, elimination criteria and weights assigned to the criteria.

Index	Criteria	Original weight	Minimum grade	Criteria weight
0	Orientation Grade	4,0	0,0	4,0
1	Publication Grade	2,0	0,0	2,0
2	Project Grade	1,5	5,0	1,5
3	Work Plan Grade	2,5	5,0	2,5

3.2 Construction of the Proposed Model

The project was developed in the Java language [10] and consists of 6 modules, totaling 3,300 lines of code. To support the data load, a parser has been implemented to read the data from the worksheet and load the modeled entities that represent the domain of the problem, for example: project, student and supervisor. From this, a filter was performed through the application of the constraints defined in the project, being: minimum grade of 3 attributes (student performance index (IRA), project note, and work plan note) and technical feasibility. It is important to note that if any of the constraints are not satisfied, the project is immediately disqualified.

In order to carry out the case study, a filter was applied to the data coming from the notice of PIBIC - 2017/2018 of UnB, selecting only projects related to the area of exact sciences, resulting a set of 409 projects to be used in the application test of implemented algorithms. In assessing the steps required to

apply the AHP method, it is seen that steps 1. Define the problem and determine the type of knowledge sought and 2. Structure the hierarchy of decision making, which in this case consisted of the definition of the weights presented in the Table 1, were executed.

For each defined criterion the alternatives preference matrix within the same criterion was calculated. This calculation is done by comparing the division of the weight of a given criterion by the weight of each of the other existing criteria. It is important to note in this case that a value can only be included in the matrix when it is greater than zero. With this, each alternative can be compared with all the others. Figure 3 presents the creation of the matrix of preferences between the criteria.

Building a set of matching matrices was necessary to convert the list of projects into a list of alternatives. From this, the execution of the method can be performed by repeating step 3 until a comparison of all the criteria and alternatives is performed, calculating the consistency index and the consistency ratio, as presented in Fig. 3. The result of the application of the AHP method will be presented in the Results section, along with the comparison of the result of the application of the PROMETHEE II method.

For the creation of the application model of the PROMETHEE II method, it was identified that step 1. Definition of the preference function, which presents the preference of the decision maker for an alternative "a" with respect to another alternative "b" in relation to a criterion and 2. Calculate the preference index, used to quantitatively compare alternatives in pairs, taking all the criteria into consideration comprehensively, were performed respectively.

In the execution of step 3. To determine the output and input flows by means of relevant preference indexes, three functions were tested in each criterion: usual, linear and Gaussian. For the linear function, the indifference and preference thresholds were defined for each criterion. Orientation Grade: 5 and 20; Publication Grade: 3 and 9; Project Grade: 3 and 8; Work Plan Grade: 5 and 12.

Step 4 of PROMETHEE II, which consists of presenting the classification alternatives according to the generated result, as well as the result of applying the AHP method will be presented in the next section.

4 Results and Discussion

The first 20 results of the application of the AHP and PROMETHEE II methods in their variations are presented in Table 2. In the analysis of this result must be considered the descending order of classification from the final grade attribute that contains the official data obtained for the projects of the notice of the Institutional Program of Scientific Initiation (ProIC/PIBIC) - 2017/2018 of UnB. In the Table 2 Rank Promethee USUAL = USUAL; Rank Promethee LINEAR = LINEAR; Rank Promethee GAUSSIAN = GAUSSIAN.

In what concerns the selection of projects, it is necessary to respect the quantity of vacancies for paid or voluntary projects existing at UnB, according

Table 2. Implementation results and case study tests.

Project	Final grade	Rank AHP	USUAL	LINEAR	GAUSSIANO
28768	100	1	1	1	1
28474	100	2	2	2	2
28480	100	3	3	3	3
28448	91	4	25	4	14
28499	91	5	26	5	15
28376	90	7	7	6	4
28511	90	8	8	7	5
28513	90	9	9	8	6
28157	88	11	11	10	10
28400	88	12	12	11	11
28401	88	13	13	12	12
28463	88	14	14	13	13
28225	88	15	4	14	7
28226	88	16	5	15	8
28227	88	17	6	16	9
28530	86	6	79	9	62
28399	86	19	46	18	23
28497	86	22	27	19	16
28299	85	18	59	17	48
28321	85	20	30	22	18
28321	85	20	30	22	18

to the rule that the first classified can be described as “Remunerated Approved”; then inserted the “Volunteer Approvals”. The other projects not disqualified by the restrictions imposed, will be ordered in a “Paid Waiting List” and ending with the “Waiting List of Volunteers”.

```
INFO  AhpExecutor:23 - Criterion: Orientation Grade
INFO  AhpExecutor:23 - Criterion: Publication Grade
INFO  AhpExecutor:23 - Criterion: Project Grade
INFO  AhpExecutor:23 - Criterion: Work Plan Grade
INFO  AhpExecutor:25 - Criteria judgement:
1,0000 2,0000 2,6667 1,6000
0,5000 1,0000 1,3333 0,8000
0,3750 0,7500 1,0000 0,6000
0,6250 1,2500 1,6667 1,0000
```

Fig. 3. Result of the first matrix coupled with the application test using AHP.

It can be seen from the analysis of the results contained in the Table 2, that the application of the methods only follows the same pattern for the first 3 projects and that the rankings generated by the application of the PROMETHEE II method using the usual and Gaussian functions generated a less consistent classification and because of this they were not used in the deepening of this case study.

The rankings generated by the application of the AHP and PROMETHEE II methods using the linear function presented a higher consistency index and were therefore analyzed in a higher level of detail to compose the proposed method that will provide conditions to reliably rank and structure project classifications and research grants from UnB.

The proposal made from the results generated in this case study, consists in the use of the PROMETHEE II method using the linear function, since it presented greater efficiency in the classification of the projects and the resulting ordering was considered consistent and coherent with the existing values in the analyzed attributes.

It is worth mentioning that the implementation of the application with the use of the AHP and PROMETHEE II methods used the adjusted criteria for some items that in the notice had a maximum scoring limit, focusing on the application of the methods in the attributes of "Orientation Grade", "Work Plan Grade", the "Grade Publication" and the "Grade Project", with weights defined to indicate the importance and relevance to each item.

5 Conclusion

The application of MCDA methods for ranking projects and research grants from teaching institutions proved to be satisfactory for the case study developed. It can be noticed that the results of the application of the AHP and PROMETHEE II methods in the data coming from the UnB's Scientific Initiation Program (ProIC/PIBIC) - 2017/2018, resulted in a different classification from that obtained officially for the same data.

This difference is explained by the intrinsic characteristics of the applied methods that differ from the simple sum and rank currently used in the evaluated institution. The comparison between the AHP and PROMETHEE II results showed that according to the existing criteria, the AHP and PROMETHEE II method using the linear function are the most suitable for project classification.

It is expected that the proposal made in this work can be used and provide conditions to reliably and structuredly rank project data in order to improve the quality of the program selection process used by UnB.

The application developed will be delivered to the unit responsible for the projects selection of the UnB, where the rankings can be tested from the perspective proposed in this study and a commission can validate and homologate the results obtained. It can then be integrated with existing systems in order to optimize their execution.

The criteria suggested as relevant to the process may be adequate according to similar needs, considering the constraints and particularities of each case.

With this, the steps followed in this project can be replicated and created standards of evaluation and selection of research projects with greater coherence, being possible the use of the application by any Institution that wishes to evaluate its projects.

Acknowledgments. This research work has the support of the Research Support Foundation of the Federal District (FAPDF).

References

1. de Araújo, A.G., de Almeida, A.T.: Apoio à decisão na seleção de investimentos em petróleo e gás: uma aplicação utilizando o método PROMETHEE. In: Gest. Prod. 2009, vol. 16, no. 4, pp. 534–543 (2009)
2. Belton, V., Stewart, T.: Multiple Criteria Decision Analysis: An Integrated Approach. Springer, Dordrecht (2002). https://doi.org/10.1007/978-1-4615-1495-4
3. Bouyssou, D.: Building Criteria: A Prerequisite For MCDA. Universite de Paris Dauphine Place du Marechal De Lattre de Tassigny, LAMSADE (1990)
4. Brans, J.P., Vincke, P.H.: A preference ranking organization method, the PROMETHEE method for MCDM. Manage. Sci. **31**, 647–656 (1985)
5. Campos, V.R.: Modelo de apoio à decisão multicritério para priorização de projetos em saneamento (2011). http://www.teses.usp.br/teses/disponiveis/18/18157/tde-08022012-104925/pt-br.php
6. Carladous, S., Tacnet, J.M., Dezert, J., Han, D., Batton-Hubert, M.: Evaluation of efficiency of torrential protective structures with new BF-TOPSIS methods. In: 2016 19th International Conference on Information Fusion (FUSION), pp. 2267–2274, July 2016
7. Chatterjee, K., Hossain, S.A., Kar, S.: Prioritization of project proposals in portfolio management using fuzzy AHP. OPSEARCH **55**(2), 478–501 (2018)
8. Chen, L., Xu, Z.: A new prioritized multi-criteria outranking method: the prioritized PROMETHEE. J. Intell. Fuzzy Syst. **29**(5), 2099–2110 (2015). https://doi.org/10.3233/IFS-151686
9. e Costa, C.B., Vincke, P.: Multiple criteria decision aid: an overview. In: Bana e Costa, C.A. (ed.) Readings in Multiple Criteria Decision Aid, pp. 3–14. Springer, Heidelberg (1990). https://doi.org/10.1007/978-3-642-75935-2_1
10. Deitel, P., Deitel, H.: Java How to Program. Prentice Hall Press, Upper Saddle River (2011)
11. Elmokrini, A., Benabbou, L., Berrado, A.: Multi-criteria distribution network selection. In: 2015 10th International Conference on Intelligent Systems: Theories and Applications (SITA), pp. 1–6 (2015). https://doi.org/10.1109/SITA.2015.7358393
12. Haddad, M., Sanders, D., Bausch, N., Tewkesbury, G., Gegov, A., Hassan, M.: Learning to make intelligent decisions using an expert system for the intelligent selection of either PROMETHEE II or the analytical hierarchy process. In: Arai, K., Kapoor, S., Bhatia, R. (eds.) IntelliSys 2018. AISC, vol. 868, pp. 1303–1316. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-01054-6_91
13. Hall, M., Frank, E., Holmes, G., Pfahringer, B., Reutemann, P., Witten, I.H.: The weka data mining software: an update. ACM SIGKDD Explor. Newslett. **11**(1), 10–18 (2009)
14. López, H.M.L., de Almeida, A.T.: Utilizando PROMETHEE V para seleção de portfólio de projetos de uma empresa de energia elétrica. Production **24**(3), 559–571 (2014)

15. Ho, W., Ma, X.: The state-of-the-art integrations and applications of the analytic hierarchy process. Eur. J. Oper. Res. **267**(2), 399–414 (2018)
16. Karasakal, E., Aker, P.: A multicriteria sorting approach based on data envelopment analysis for R&D project selection problems. In: Omega, December 2017, vol. 73, pp. 79–92 (2017)
17. Tavakkoli-Moghaddam, R., Sotoudeh-Anvari, A., Siadat, A.: A multi-criteria group decision-making approach for facility location selection using PROMETHEE under a fuzzy environment. In: Kamiński, B., Kersten, G.E., Szapiro, T. (eds.) GDN 2015. LNBIP, vol. 218, pp. 145–156. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-19515-5_12
18. Morton, A., Keisler, J.M., Salo, A.: Multicriteria portfolio decision analysis for project selection. In: Greco, S., Ehrgott, M., Figueira, J. (eds.) Multiple Criteria Decision Analysis, pp. 1269–1298. Springer, New York (2016). https://doi.org/10.1007/978-1-4939-3094-4_28
19. Mussa, M., Cordeiro, R., Freitas, R., Hora, H., Silva, S.: Priorização de projetos de ti através da modelagem do processo e utilização do método promethee. Revista de Gestão dos Países de Língua Portuguesa **17**(1), 56–75 (2018)
20. Saaty, T.: The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. Advanced book program, McGraw-Hill (1980). https://books.google.com.br/books?id=Xxi7AAAAIAAJ
21. da Silva, A.M., de Melo, R.M.: Uma abordagem multicritério para a seleção de serviços de consultoria e certificação de sistemas de gestão da qualidade. In: Gest. Prod., 28 September 2017 (2017)
22. Soylu, B.: Integrating prometheeii with the tchebycheff function for multi criteria decision making. Int. J. Inf. Technol. Decis. Making **9**(4), 525–545 (2010)
23. Thokala, P., et al.: Multiple criteria decision analysis for health care decision making—an introduction: report 1 of the ispor mcda emerging good practices task force. Value Health **19**(1), 1–13 (2016). https://doi.org/10.1016/j.jval.2015.12.003, http://www.sciencedirect.com/science/article/pii/S1098301515051359
24. Toinard, C., Ravier, T., Céerin, C., Ngoko, Y.: The promethee method for cloud brokering with trust and assurance criteria. In: 2015 IEEE International Parallel and Distributed Processing Symposium Workshop (2015)
25. Wang, C., Zhou, F., Vergeest, J.: Multi-objective optimization for the functional configuration design of mobile devices using analytic hierarchy process. In: 2009 Second International Symposium on Intelligent Information Technology and Security Informatics, pp. 137–142 (2009). https://doi.org/10.1109/IITSI.2009.37