Multicriteria Decision Method for Project Ranking Considering Uncertainty

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Abstract: Frequently, decision makers face the challenge of selecting projects to be executed. Resources are not enough for funding all of them. In this challenge, they need the support of a tool or method, due to several criteria to be considered simultaneously. Multicriteria decision methods can provide a good support. However, as inherent to all estimation in projects, uncertainty must be addressed. This works proposes a method for incorporating uncertainty in project selection using ELECTRE II method and Monte Carlo simulation.

1 INTRODUCTION

In general, companies face a challenge when need to decide about projects to be executed. Available resource isn't enough for executing all of them simultaneously Dutra et al. (2014); Agapito et al. (2019). It leads decision makers to select a subset of projects to be included in company's portfolio, among the candidates Abbassi et al. (2014). For selection, a ranking prioritizing projects is helpful, considering those which are more aligned to the strategies and marketing demand, aiming to execute the best set of projects Perez and Gomez (2014).

The correct selection of projects is essential for companies, avoiding waste of resources Urli and Terrien (2010). Applying formal project selection methods increases the chances of success Dutra et al. (2014).

When selecting projects, decision maker needs to compare several criteria. Multicriteria Decision Methods (MCDM) help it, allowing elaborate a ranking of options, enumerating from the best to the worst Wallenius et al. (2008). MCDM applications have grown in academic work publications Sadi-Nezhad (2017).

Preference Ranking Organization Method for Enrichment Evaluation II (PROMETHEE II), *VIseKriterijumska Optimizacija I Kompromisno Resenje* (VIKOR), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and *Elimination Et Choix Traduisant la Réalité* II (ELECTRE II) are examples of MCDM Brans and Vincke (1985); Opricovic (2012); Hwang (1981); Roy and Bertier (1973). All of them can offer, at the end, a ranking from the best to the worst options Martins and Marcondes (2020).

For using MCDM, specialists must evaluate the criteria, estimating objective values for each project. It includes uncertainty in selection, once it is inherent in the estimation process, and a normal and inevitable phenomenon in projects Bohle et al. (2015). Therefore, uncertainty should be considered when applying the MCDM.

Three-point estimation method allows to incorporate the variation caused in the values due to uncertainty, given that, instead of estimating by a single value, three are used: most likely, optimistic and pessimistic PMI (2017). These three values can be used to define a triangular probability distribution for parameters under analysis, and dealing with uncertainty in evaluations Stein and Keblis (2009).

Monte Carlo simulation is a tool for considering uncertainty in evaluations PMI (2017); Marcondes et al. (2017). Each simulation round draws a random value for the parameters, based on the defined probability distribution. After several rounds, you can observe the variation in the results.

This work proposes a way of considering uncertainty in ranking projects by MCDM. For each project, three-point estimation is proceeded, triangular distributions are set and simulation done. The proposal is exemplified by applying ELECTRE II method over a set of eleven real software development projects (the same procedure could be applied to any

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other MCDM listed above).

The remaining of this paper is organized as follow: Section 2 presents the principles of multicriteria decision methods, detailing ELECTRE II; the importance of uncertainty in project selection problems is presented in Section 3; Section 4 proposes a method for selecting projects considering uncertainty; which is exemplified by a real problem in Section 5; Section 6 concludes the work.

2 MULTICRITERIA DECISION MAKING

Single criterion decisions are very intuitive, once one must choose the alternative with higher preference score. However, when decision depends on more than one criterion, the choice must consider, for instance, weights and conflicts among criteria. It demands more sophisticated methods Tzeng and Huang (2011).

For project selection, it is important to use MCDM to find an appropriate assessment, once it often is involved with multiple criteria. These methods allow to rank different alternatives subject to qualitative criteria. Its application has been rising in the past few years Sadi-Nezhad (2017).

There are a lot of MCDM in the literature. Four of these methods are: Preference Ranking Organization Method for Enrichment Evaluation II (PROMETHEE II), *VIseKriterijumska Optimizacija I Kompromisno Resenje* (VIKOR), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and *ELimination Et Choix Traduisant la Réalité* II (ELECTRE II). PROMETHEE II can be used when a complete classification is necessary in the presence of a finite set of alternatives. VIKOR solves decision problems with criteria of the same priority, identifying the alternative closest to the ideal (allows the definition of rankings). TOPSIS evaluates the performance of alternatives with several comparison criteria. The closer to the ideal solution and far from the non-ideal, the better the alternative Martins and Marcondes (2020). ELECTRE II allows the calculation of the agreement and disagreement indices for each alternative, allowing, with these values, the construction of a preference classification Tzeng and Huang (2011).

For project selection, MCDM must follow the steps (adapted from Opricovic and Tzeng (2004)):

- Establishing evaluation criteria that relate to goals;
- Evaluating projects in terms of criteria;
- Applying an MCDM;
- Accepting one alternative (or some of them) as selected.

An MCDM that is able to produce a final ranking is useful. This ranking can indicate a prioritizing list of projects, allowing the selection of the first one, two, three, four, and so on, options, depending on the number of projects to be executed. Any method presented in this section allows decision makers to achieve this requirement. For this work, the example presented in Section 5 uses ELECTRE II.

2.1 *Elimination Et Choix Traduisant la Réalité* II (ELECTRE II)

There is four ELECTRE (in English Elimination and Choice Translating Reality) methods (I, II, III and IV). They have different applications Opricovic and Tzeng (2006):

- ELECTRE I for selection, but without a ranking;
- ELECTRE II, III and IV for ranking problems;
- ELECTRE II and III when it is possible and desirable to quantify the relative importance;
- ELECTRE III incorporates the fuzzy nature of decision making;
- ELECTRE IV when quantification is not possible.

The ELECTRE II method was chosen due to the possibility of ranking the alternatives and because, in project selection problems, it is possible quantifying relative importance. It is an approach for multicriteria decision, based on the outranking relation. It works with the concepts of concordance and discordance. For each alternative (projects, in this paper), these two indexes are calculated, considering all criteria Opricovic and Tzeng (2006); Tzeng and Huang (2011).

For identifying how much alternative a is, at least, as good as alternative b, one must calculate concordance index $C(a,b)$. Discordance index $D(a,b)$ is a measure of how much strictly preferable alternative b is in comparison to alternative a Tzeng and Huang (2011).

Some quantities are needed for calculating these indexes Tzeng and Huang (2011).

$$I^{+}(a,b) = \{C_i \mid g_i(a) > g_i(b)\} \quad (1)$$

$$I^{=}(a,b) = \{C_i \mid g_i(a) = g_i(b)\} \quad (2)$$

$$I^{-}(a,b) = \{C_i \mid g_i(a) < g_i(b)\} \quad (3)$$

$$W^{+}(a,b) = \sum_{j \in I^{+}(a,b)} w_i \quad (4)$$

$$W^{=}(a,b) = \sum_{j \in I^{=}(a,b)} w_i \quad (5)$$

$$W^{-}(a,b) = \sum_{j \in I^{-}(a,b)} w_i \quad (6)$$

where:

- i represents the i^{th} selection criterion ($i = 1, ..., n$);
- $g_i(j)$ indicates the preference value of the i^{th} selection criterion for alternative j ($j = 1, ..., J$);
- w_i is the weight of the i^{th} selection criterion;
- $C_i \in [0,1]$ indicates if, for the i^{th} selection criterion, alternative b is strictly preferable in comparison to alternative a, or the opposite, respectively.

The concordance index $C(a,b)$ of alternative a with respect to alternative b is Tzeng and Huang (2011):

$$C(a,b) = \frac{W^{+}(a,b) + W^{=}(a,b)}{W^{+}(a,b) + W^{=}(a,b) + W^{-}(a,b)} \quad (7)$$

The discordance index $D(a,b)$ of alternative a with respect to alternative b is Tzeng and Huang (2011):

$$D(a,b) = \frac{max_{i \in I^{-}(a,b)} |g_i(a) - g_i(b)|}{max_{i \in I}(g_i^{*} - g_i^{**})} \quad (8)$$

where:

- g_i^{*} is the highest preference value for the i^{th} selection criterion;
- g_i^{**} is the lowest preference value for the i^{th} selection criterion.

For ranking the alternatives, decision maker must compare the lists of concordance index, in descending order, discordance index, in ascending order.

Alternatively, a final ELECTRE II index could be calculated by:

$$e = C(a,b) - D(a,b) \quad (9)$$

The ranking is constructed ordering e in descending order, from the highest (best option) to the lowest (worst option) values.

3 UNCERTAINTY

For applying MCDM in projects, it is necessary that decision maker evaluates and estimates the values of criteria for each project. Uncertainty is an inherent effect of estimating and forecasting Marcondes et al. (2017).

When defining the value of any parameter, the decision maker (or project specialist) chooses the one that best represents his evaluation. However, this estimation may not be accurate. Or even, if more than one person evaluates and estimates such parameters, the estimated values may differ.

For instance, if three specialist in the projects define their values for some selection criteria, instead of a single value for each one, they are likely to have a range of values. It represents the uncertainty in parameter definition, impacting in final decision of projects.

For minimizing this impact, instead of working with a single value, three-point estimation can be useful. It is done by estimating the values most likely, optimistic and pessimistic. The most likely value is the estimation of the parameter best understanding by evaluator (probably, this the value estimated if a single point estimation is proceeded). Optimistic and pessimistic values must reflect the best and worst scenarios, respectively PMI (2017).

These three values can be used to construct a triangular probability distribution PMI (2017), as presented in Figure 1:

- parameter a is equal to pessimistic estimation;
- parameter b is equal to optimistic estimation;
- parameter c is equal to most likely estimation.

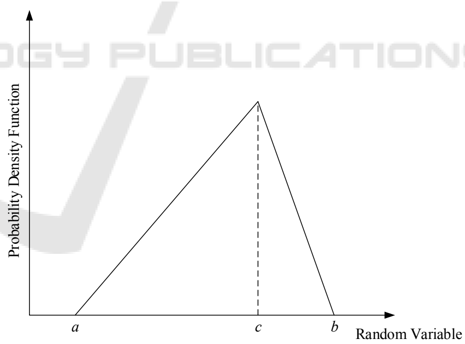

Figure 1: Triangular distribution based on three point estimation.

4 PROPOSED METHOD

The method proposed in this work is for supporting decision makers in project selection. Its final objective is a definition of a ranked list of projects, from the best option to the worst, for supporting decision of which ones to execute. It is built based on ELECTRE II method, considering uncertainty.

For each project, three parameters are estimated for each criterion. Triangular distributions are set, as described in Section 3. Also the weights of criteria must be established.

Monte Carlo simulation allows incorporating uncertainty in evaluation. For each round (*m* rounds), project parameters are randomly chosen based on the triangular distributions. The values are normalized in a common scale, for avoiding distortion due to different value ranges. Then ELECTRE II evaluation is executed. At the end of rounds, there are *m* sets of *e* indexes calculated, and a final *e* index set is achieved defining the mean of them.

The algorithm for ranking projects, with a stochastic approach to address uncertainty in the definition of parameters and using Monte Carlo simulation is the following:

```
Begin

    % m is the number of Monte Carlo rounds.
    Define m

    Read pessimistic_project_estimation

    Read most_likely_project_estimation

    Read optimistic_project_estimation

    Read criteria_weigths

    Repeat m times

        {

        Define ramdomly project_parameters

        Normalize values

        Calculate e_index

        Store e_index

        }

    Calculate mean of m sets of e_index values

    Define final ranking

End
```

5 NUMERICAL EXAMPLE

For exemplify, the method proposed in Section 4 was applied in a set of eleven real software development projects, from a software R&D service provider. Three specialists on software projects and market from the company estimated the values for four criteria:

- **C1 - Return/risk rate (weight - 0,4):** a ratio between the estimated return and the associated risk (from 1 - the lowest to 10 - the highest);
- **C2 - Competitiveness improvement (weight - 0,3):** the capacity of project for improving company competitiveness (from 1 - the lowest to 10 - the highest);
- **C3 - Market potential (weight - 0,2):** the capacity of project for improving market share or market insertion (from 1 - the lowest to 10 - the highest);
- **C4 - Degree of innovation (weight - 0,1):** how innovative the project is (from 1 - the lowest to 10 - the highest).

The objective was to select three projects for execution. They should be chosen in order to be more aligned with the company's strategies and met the defined criteria in the best way. Preparing a ranking of projects (based on the criteria and using ELECTRE II method), the three best ranked ones should be executed.

The first step was the definition, by the specialists consulted, of the values of project estimations. For each of these, they defined the most likely, pessimistic and optimistic values, of the criteria defined for selection. Table 1 presents most likely values, which is generally used when single estimation is applied in selection. Tables 2 and 3 present pessimistic and optimistic values, respectively, to allow applying the selection considering the uncertainty.

Table 1: Projects Characteristics - Most Likely.

	Criteria			
Project	C1	C2	C3	C4
A	10	3	2	3
B	8	5	8	7
C	2	6	5	4
D	1	2	9	10
E	5	9	10	6
F	6	3	2	2
G	7	7	7	9
H	3	5	3	3
I	8	1	6	7
J	9	9	2	4
K	3	8	1	5

Before simulation using the proposed method, one was made using the single estimation (values presented in Table 1) as a reference for comparing the results. In this case, the projects that would be selected are J, E and G. They were the best ranked by ELECTRE II *e* index, as can be seen in graphic of Figure 2, presenting the best option on the left, and

Table 2: Projects Characteristics - Pessimistic.

	Criteria			
Project	C1	C2	C3	C4
A	8	2	1	2
B	7	4	7	6
C	1	4	3	3
D	1	1	7	9
E	3	6	8	5
F	5	2	1	1
G	5	5	5	8
H	2	4	2	2
I	7	1	4	5
J	6	8	1	3
K	2	7	1	3

Table 3: Projects Characteristics - Optimistic.

	Criteria			
Project	C1	C2	C3	C4
A	10	4	4	5
B	9	6	9	8
C	4	7	6	5
D	2	3	10	10
E	6	10	10	7
F	7	6	3	4
G	9	8	9	10
H	4	6	5	4
I	9	3	7	8
J	10	10	3	5
K	5	10	2	7

the worst on the right.

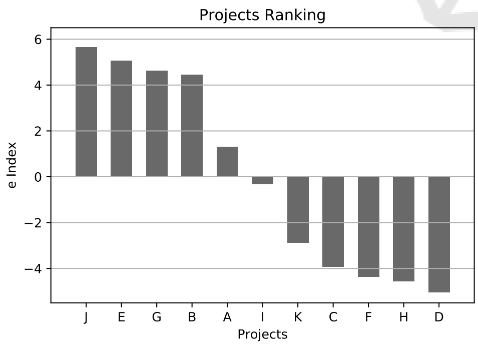

Figure 2: Projects Ranking - Without Uncertainty.

Applying the selection with uncertainty, as presented in Section 4 (Monte Carlo simulation with 10,000 rounds), the ranking of projects changed to the one shown in the Figure 3, indicating projects G, J and B for execution.

Comparing these two results (without and with uncertainty), some differences are identified. The first four positions of ranking changed from J, E, G and B to G, J, B and E. And the best ranked project changed from J to G. Another difference was the inversion observed in 8th and 9th ranking positions (from C / F to F / C). The best three options, in simulation with uncertainty, were projects G, J and B (comparing to result without uncertainty, project B was included, and project E excluded). These changes showed the importance of considering uncertainty in project selection.

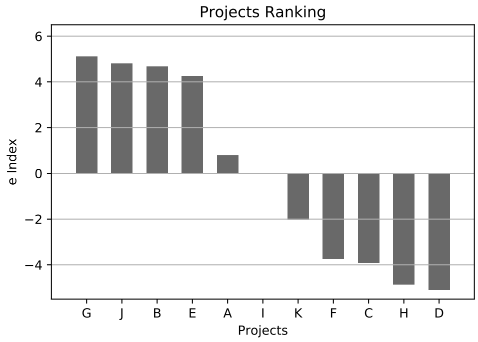

Figure 3: Projects Ranking - With Uncertainty.

Finally, considering the uncertainty in selection, the chosen projects were G, J and B. They were the best ones in ELECTRE II *e* index ranking.

6 CONCLUSIONS

Project selection is a challenge in portfolio management in companies. Generally, there is no enough resources for funding all listed projects. Due to this, decision makers need to choose those which will be executed.

The selection is often not direct, as it depends on several criteria, which must be evaluated simultaneously. Some of them can also be in conflict with each other.

Multicriteria decision methods can help decision makers in selection. They are a good solution for handling decisions that involve multiple criteria, as: PROMETHEE II, TOPSIS, VIKOR and ELECTRE II.

However, these methods based the decision on values estimated for the criteria. As an estimation, these values can bring uncertainty for selection.

The work presented in this paper proposes a method to incorporate uncertainty in decision, supporting decision makers. Instead of estimation with a single value, it is done using three: most likely, pessimistic and optimistic. Based on them, one proceeds a Mote Carlo simulation, defining the parameters randomly in each round (in this case, applying triangular distribution).

In the numerical example presented, the target was choosing three of eleven projects. The results indicated an important change. Without uncertainty, the selected projects would be J, E and G. However, the ELECTRE II *e* index ranking changed when selecting with uncertainty. After Monte Carlo simulation (10,000 rounds), projects indicated for execution were G, J and B. The best option changed from J to G. And the project E, presented in the list when no uncertainty was considered, was excluded of the final list, including project B. It highlighted the importance of considering uncertainty in selection, due to its impact on final results.

For future works, some issues must be considered in selection:

- Apply a fuzzy approach to address uncertainty rather than Monte Carlo simulation;
- Constraints as developers and equipment available;
- Evaluate projects with more than one MCDM;
- Time needed for each project execution.

REFERENCES

Abbassi, M., Ashrafi, M., and Tashnizi, E. S. (2014). Selecting balanced portfolios of R&D projects with interdependencies: A cross-entropy based methodology. *Technovation*, 34(1):54–63.

Agapito, A. O., Vianna, M. F. D., Moratori, P. B., Vianna, D. S., Meza, E. B. M., and Matias, I. O. (2019). Using multicriteria analysis and fuzzy logic for project portfolio management. *Brazilian Journal of Operations & Production Management*, 16(2):347–357.

Bohle, F., Heidling, E., and Schoper, Y. (2015). A new orientation to deal with uncertainty in projects. *International Journal of Project Management*, 34(7):1384–1392.

Brans, J. P. and Vincke, P. (1985). A preference ranking organisation method: (the promethee method for multiple criteria decision-making). *Management Science*, 31(6):647–656.

Dutra, C. C., Ribeiro, J. L. D., and de Carvalho, M. M. (2014). An economic-probabilistic model for project selection and prioritization. *International Journal of Project Management*, 32(6):1042–1055.

Hwang, C.L.; Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications*. Springer-Verlag, Nova York, EUA.

Marcondes, G. A. B., Leme, R. C., Leme, M. S., and da Silva, C. E. S. (2017). Using mean-Gini and stochastic dominance to choose project portfolios with parameter uncertainty. *The Engineering Economist*, 62(1):33–53.

Martins, D. T. and Marcondes, G. A. B. (2020). Project portfolio selection using multi-criteria decision methods. In *IEEE International Conference on Technology and Entrepreneurship – ICTE*.

Opricovic, S. (2012). *Multi-criteria optimization of civil engineering systems (in Serbian, Visekriterijumska optimizacija sistema u gradjevinarstvu)*. PhD thesis, Faculty of Civil Engineering, Belgrade.

Opricovic, S. and Tzeng, G.-H. (2004). Compromise solution by mcdm methods: A comparative analysis of vikor and topsis. *European Journal of Operational Research*, 156(2):445–455.

Opricovic, S. and Tzeng, G.-H. (2006). Extended vikor method in comparison with outranking methods. *European Journal of Operational Research*, 178(2):514–529.

Perez, F. and Gomez, T. (2014). Multiobjective project portfolio selection with fuzzy constraints. *Annals of Operations Research*, 236:1–23.

PMI (2017). *A Guide to the Project Management Body of Knowledge*. Project Management Institute, Atlanta, EUA, 6 edition.

Roy, B. and Bertier, P. (1973). La methode ELECTRE II: Une application au media-planning. *Operational Research*, page 291–302.

Sadi-Nezhad, S. (2017). A state-of-art survey on project selection using mcdm techniques. *Journal of Project Management*, 2(1):1–10.

Stein, W. E. and Keblis, M. F. (2009). A new method to simulate the triangular distribution. *Mathematical and Computer Modelling*, 49(5-6):1143–1147.

Tzeng, G. H. and Huang, J. J. (2011). *Multiple attribute decision making: methods and applications*. Chapman and Hall/CRC.

Urli, B. and Terrien, F. (2010). Project portfolio selection model, a realistic approach. *INTERNATIONAL TRANSACTIONS IN OPERATIONAL RESEARCH*, 17(6):809–826.

Wallenius, J., Dyer, J. S., Fishburn, P. C., Steuer, R. E., Zionts, S., and Deb, K. (2008). Multiple criteria decision making, multiattribute utility theory: Recent accomplishments and what lies ahead. *Management Science*, 54(7):1336–1349.