Innovation Project Selection Considering Stochastic Weighted Product Model

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Abstract: Nowadays, organizations and companies are increasingly seeking to innovate in products and processes. In general, innovation materializes in the form of project execution. However, such projects are complex to implement, the evaluation of which requires understanding and knowledge of many factors. This makes its selection also difficult, given that it is necessary to experiment, which may or may not be successful, involving volatility and uncertainty, which increases when the open approach is implemented (to compensate for a lack of information, resources and skills). The selection of innovation projects can be supported by appropriate tools, in order to assist the decision maker in their choices. Multi-criteria decision methods (MCDM) can provide this support, especially if they take uncertainty into account. This work proposes the application of the Weighted Product Model (WPM), an MCDM, in the selection of innovation projects. To address uncertainty, assessments performed by more than one expert are translated into three-point estimates and Monte Carlo simulation applied for a stochastic approach. The proposed method is applied to the selection in a group of 13 innovation projects, as an example.

1 INTRODUCTION

In boosting the competitiveness and growth of companies, innovation is a fundamental element. One of its challenges is choosing the "right" projects to which the necessary resources must be allocated (Si et al., 2022). Managing innovation is a process that is strongly linked to the need to choose which ideas and projects to invest in. This is one of the most important aspects. Although the selection processes are part of the daily life of organizations, they involve people, who use their own forms of calculations or evaluations, which can lead to subjective conclusions (Havis, 2020; Basilio et al, 2023).

The resources available for projects, especially those for innovation, are generally limited and scarce in organizations, preventing all projects presented or proposed from being developed simultaneously (Dutra et al., 2014; Agapito et al., 2019; Lee et al., 2020). As a result, decision makers must choose, based on their pre-defined criteria, which ones will be effectively carried out (Abbassi et al., 2014).

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Some approaches to deal with this situation are known, project ranking being one of them. It allows a choice based on structured forms, especially if objective selection criteria are defined, to better meet the organization's desires and marketing positioning (Perez and Gomez, 2014).

The chances of successful project execution increase when formal selection methods are applied (Dutra et al., 2014). Eventual waste of scarce resources can be avoided or minimized, when there is the correct choice of the set of projects to be executed (Abbassi et al., 2014; Agapito et al., 2019).

The nature of project decisions makes their realization complex, since several criteria must be considered simultaneously (Tzeng and Huang, 2011). This is especially true for innovation projects, considering that unexpected results can negatively impact the future of the organization (Lee et al., 2020).

Multicriteria Decision Methods (MCDM) are tools that help solve complex engineering problems and can be used for this type of choice. Ranking the alternatives in order of priority/preference is a possible solution in some of these methods (Wallenius et al., 2008; Mavrotas and Makryvelios, 2021).

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The use of MCDM has grown in academic publications, some examples of which are listed below (Sadi-Nezhad, 2017; Martins and Marcondes, 2020; Basilio et al, 2022):

- 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);
- *Elimination Et Choix Traduisant la Réalité* II (ELECTRE II);
- Weighted Product Method (WPM).

In turn, every decision about projects to be carried out must be taken based on estimates, uncertainty being one of its inherent characteristics (Bohle et al., 2015). Such uncertainty can influence the selection result, as shown in the results of Marcondes et al. (2017); Marcondes (2021).

There are several ways to deal with uncertainty, the three-point estimate being one of those indicated in PMI (2021). In this case, instead of estimating by a single value, three are used (worst case, most likely and best case). The treatment of such variation can be done through Monte Carlo simulation or fuzzy numbers (Deng, 2014; Wang, 2015; Marcondes, 2021).

Once performed a three-point estimate, each parameter can be characterized by a triangular probability distribution, which feeds a Monte Carlo simulation. At each new round, the parameters receive random values, based on the defined distribution, allowing, at the end of the simulation, to observe how the values varied and their conclusions.

The purpose of this work is to consider uncertainty in the application of an MCDM for the selection of innovation projects. Each project is evaluated by different experts, considering the various criteria defined for the choice. These assessments can be characterized in three-point estimation, allowing the Monte Carlo simulation to be carried out. The MCDM chosen for this work was WPM, since it was used successfully in some works for selection and the criteria weights on the decisions outcome is significant. (Goswami et al., 2020; AlAli et al., 2023; Ayan et al, 2022).

The uncertainty addressed in this work is the one introduced in the estimation process, naturally, due to the error in values attributed to the decision criteria for each alternative.

The remaining of this paper is organized as follow: in Section 2 the characteristics of innovation projects are summarized; Section 3 presents the principles of multicriteria decision methods, detailing WPM; the importance of uncertainty in project selection problems is presented in Section 4; Section 5 proposes a method for selecting projects considering uncertainty; which is exemplified by a real problem in Section 6; Section 7 concludes the work.

2 INNOVATION PROJECTS

Innovation projects often require the dissemination of knowledge and its integration to achieve their objectives. As this process is affected by multiple factors, as a consequence there is high uncertainty. The integration and dissemination of knowledge during project implementation is complex (Xu et al, 2023).

The investment decision and selection of innovation projects has become a point of attention and care in research. Due to their characteristics, innovation projects require, as much as possible, an assessment of all factors involved. Its results have great potential for financial return and increased market capillarity and scale, but require a lot of attention when selecting which ones to execute (Dong et al, 2023).

The development of new innovative products is essential for sustainable business growth and improved competitiveness. This means that, annually, many financial resources are invested in the research and development of new products. It makes innovation a fundamental element for companies and organizations (Si et al., 2022).

Due to the characteristics of novelty and change, innovation projects can be more difficult to control and, consequently, to be chosen/defined. They bring with them the need to experiment, succeed or fail, uncertainty and volatility, adaptation to unforeseen opportunities and, above all, creativity. An additional factor of complexity is the tendency towards open innovation, as there is active cooperation with various actors (internal and external), in order to compensate for any shortage of information, external and skills. (Dybal and Wang., 2017).

Once innovation projects are fundamentals for companies and organizations today, care must be taken with investments. Generally, innovation is achieved by carrying out projects. This increases the importance and responsibility of those who need to make the selection and define which ones should be executed or not.

3 WEIGHTED PRODUCT MODEL (WPM)

Structured decisions of choosing between alternatives must present clear decision criteria. When such a choice uses only one criterion, for example, choosing only the lowest price, the decision is simple, just comparing the values. However, as more criteria are considered simultaneously, the decision becomes more complex. Especially, if there is a conflict between the established criteria (Tzeng and Huang, 2011).

Multicriteria Decision Methods (MCDM) have been widely used in project selection and significant advances in techniques have been made in recent years (Sadi-Nezhad, 2017; Sahoo and Goswami, 2023). Weighted Product Model (WPM) is an easy-to-apply method that allows the generation of a prioritized list (ranking) among the evaluated alternatives, considering multiple criteria and weights in the decision.

WPM is an MCDM, based on weighted multiplication of proportions (ratios) between alternative values. One of its advantages is that it allows the independent evaluation of the dimensions used in the different criteria, as the ratios between the values are always used. The comparison is pair by pair (Triantaphyllou and Sanchez, 1997). The results obtained from its application allow one to rank the alternatives, in order of preference.

Considering a selection to be done for m alternatives and n criteria, WPM is performed like following.
Step 1 - Calculate the product P for each alternative related to all other alternatives(Triantaphyllou and Sanchez, 1997):

$$P(A_i/A_j) = \prod_{k=1}^{n} \left(a_{ik}/a_{jk}\right)^{w_k} \quad (1)$$

where:
i and j are the alternatives ($i = 1,...,m$ and $j = 1,...,m$)
k is the selection criteria ($k = 1,...,n$)
a_{ik} and a_{jk} are the values for alternatives i and j, respectively, for the criterion k
w_k is the the weight for the criterion k

After this step, one has m P values for each alternative.
Step 2 - Calculate wpm value for each alternative (geometric mean of values):

$$wpm_i = \sqrt[m]{\prod_{j=1}^{m} P(A_i/A_j)} \quad (2)$$

for $\forall j$.

Step 3 - Organize alternatives in descending order of wpm values. It is feasible to determine the best alternatives using this ranking of preferences.

4 UNCERTAINTY TREATMENT

The application of MCDM requires a decision maker, or several ones, to estimate the value to be assigned, for each alternative and in each criterion. Estimation and forecasting bring with them uncertainty (Bohle et al., 2015; Marcondes et al., 2017).

When estimating a certain value for a parameter, within his best evaluation and understanding, the decision maker assigns what he understands to be the best. However, there may be inaccuracy in this estimate. Such inaccuracy can increase if more than one person estimates values for the same parameters.

To exemplify this situation, one can imagine a group of several evaluators estimating the values for the same parameters. The most likely thing to happen is, instead of a single value for each parameter, a range of values should be obtained for each one.

To deal with uncertainty, one can apply three-point estimates and Monte Carlo simulation. In three-point estimation, each parameter to be estimated must have three values: most likely estimate, optimistic estimate, and pessimistic estimate. Optimistic and pessimistic estimates should reflect, in the estimator's view, the best and worst case scenarios, respectively. The most likely estimate should reflect the estimator's view of which scenario is most likely to occur (PMI, 2021).

In order to indicate how to generate random values in the Monte Carlo simulation, the three values for each parameter allow the construction of a triangular probability distribution, as indicated in Figure 1 (PMI, 2021):

- parameter a is equal to worst-case estimation;
- parameter b is equal to best-case estimation;
- parameter c is equal to most likely estimation.

Thus, at each new round of the Monte Carlo simulation, random values following this defined distribution can be generated. Rounds can be repeated and their results recorded. At the end, there is a set of results obtained randomly, which allow to conclude the simulation.

5 PROPOSED METHOD

The final objective is to achieve a ranking of projects to support the selection. The method proposed in this

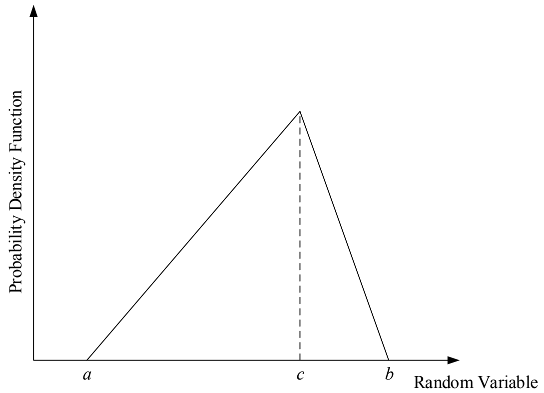

Figure 1: Triangular distribution based on three point estimation.

work follows the steps described following.

- **Step 1:** A group of specialists estimates the value for each of *m* projects considering all *n* criteria. It is better they use the same range of values (for instance, from 1 to 10). Otherwise, the estimations must be normalized before proceeding. The estimated values for each parameter lead to the definition of a three-point estimate.
- **Step 2:** The three-point estimate from Step 1 allows to define a triangular distribution for each parameter (each criterion evaluation for each project). It allows the stochastic approach to be applied.
- **Step 3:** Monte Carlo simulation is proceeded. For every run, a new random value is generated for each parameter, based on the triangular distribution respectively defined. *wpm* values are calculated and stored for the final evaluation.
- **Step 4:** After all runs of simulation, it is calculated a mean of *wpm* values. These means values allows one to prepare a final ranking, of descending values, considering the stochastic approach.

Uncertainty is treated in this proposed model by the three-point estimate performed, its respective conversion into a triangular distribution and the subsequent application of Monte Carlo simulation for a stochastic approach.

6 NUMERICAL EXAMPLE

As an example, the proposed method in Section 5 was applied in the selection carried out by a scientific and technological institution, for a call to finance three innovative projects with a pre-defined maximum budget. All proposals were evaluated by three experts, who indicated, according to their experience, the grades for each criterion. The values indicated by the evaluators allowed the composition of the three-point estimate.

Table 1: Projects Parameters Estimates C1/C2/C3.

Project	C1			C2			C3		
	WC	ML	BC	WC	ML	BC	WC	ML	BC
A	2	3	5	8	9	10	4	5	7
B	8	9	10	6	7	8	6	7	8
C	3	3	4	1	1	2	8	9	10
D	1	1	2	6	7	7	1	2	2
E	4	5	7	1	1	3	2	3	5
F	8	9	10	4	6	7	1	1	2
G	9	9	10	7	7	8	8	8	9
H	5	6	6	5	7	7	6	8	8
I	5	6	8	1	2	4	4	5	7
J	8	10	10	8	10	11	4	6	7
K	1	2	2	3	3	4	5	6	6
L	3	4	5	7	8	8	1	2	4
M	3	4	4	5	6	6	6	8	9

The criteria used in the evaluation are listed in the sequence. And the evaluations carried out, already in the three-point estimation format, are presented in Tables 1 and 2 (WC is the acronym for worst-case, ML is the acronym for most likely and BC is the acronym for best-case).

- **C1 - Feasibility of technical execution (weight - 0,2):** Evaluating the proposal presented, it must be verified whether the project has technical feasibility. (from 1 - the worst to 10 - the best);
- **C2 - Feasibility of execution within the proposed deadline (weight - 0,2):** Evaluating the proposal presented, it must be verified whether the project is feasible within the indicated deadline. (from 1 - the worst to 10 - the best);
- **C3 - Expected financial return (weight - 0,2):** Evaluate the expected financial return for the proposed project. (from 1 - the lowest to 10 - the highest);
- **C4 - Degree of innovation (weight - 0,2):** How innovative the project is (from 1 - the worst to 10 - the best).
- **C5 - Team's ability to execute the project (weight - 0,2):** Considering the team presented in the project proposal, evaluate whether it is capable of carrying out its execution. (from 1 - the worst to 10 - the best).

The application of the method aimed at a final ranking, indicating the projects to be selected in order of preference.

The ranking obtained by executing the stochastic WPM method can be seen in the bar graph in Figure 2. It indicates that projects G, B and H should be selected, as they had the best results after the simulation carried out. It is important to highlight that, applying the WPM method in a deterministic way (using the

Table 2: Projects Parameters Estimates C4/C5.

Project	C4			C5		
	WC	ML	BC	WC	ML	BC
A	2	3	5	2	3	5
B	2	3	4	8	9	10
C	5	5	6	7	7	8
D	5	6	6	5	6	6
E	6	7	9	1	2	4
F	8	10	10	5	7	8
G	6	6	7	5	5	6
H	2	4	4	8	10	10
I	8	9	10	4	5	7
J	2	4	5	1	2	3
K	9	9	10	3	3	4
L	1	1	2	5	6	6
M	2	3	3	1	2	2

most likely estimate) the same three projects were indicated, however with a reversal of order in the ranking between projects B and H (in the deterministic values execution H was second and B the third).

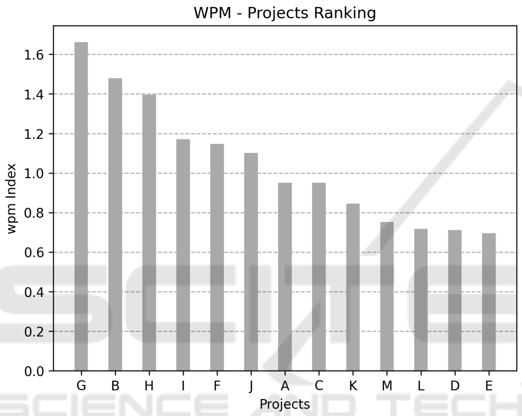

Figure 2: Projects Ranking - With Uncertainty - Stochastic WPM.

7 CONCLUSIONS

Innovation has been pursued by companies and organizations as a way of gaining market share and improving competitiveness. These types of projects are characterized by complex management and selection, as many factors must be evaluated simultaneously. In addition, they must consider the inherent risks of success and failure in results, given the need for experimentation, which increase the uncertainty of their results.

On the other hand, the scarcity of resources does not allow investing in all proposed or identified innovation projects. A selection is necessary as a way of optimizing financial, material and human resources. Which can be difficult for the decision maker.

This work proposes a method for selecting innovation projects based on WPM, an MCDM that is easy to apply and understand. Uncertainty, inherent in the selection process, is addressed using three-point estimates and Monte Carlo simulation for the stochastic approach.

As an example, the proposed method was applied to a set of 13 innovation projects, in a process that aimed to select three for execution. The result was a ranking of the projects to be carried out, in order of preference, indicating the three most suitable. This result, compared with the application of the same method in a deterministic way, indicated the same three projects, however, with a change in the ranking order, confirming the impact of uncertainty and stochastic approach in the selection. The results highlight the importance of considering the stochastic approach in selection, when there is uncertainty in the estimate, given its impact on the final selection.

As a proposal for future work, a comparison can be made between the results obtained with the WPM method with those of other MCDMs known in the literature (PROMETHEE, TOPSIS, ELECTRE and VIKOR, for example), when using the stochastic approach. Furthermore, a new method could be studied, combining WPM with the others, for a broader evaluation of the ranking. Another line of work could also be the application of the fuzzy approach to deal with uncertainty.

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