Evaluation and Selection of Innovation Projects

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Abstract
Innovation plays a major role in the growth and economic competitiveness of companies, industries and countries. Innovation projects are strong consumers of resources and their potential benefits occur in a long time horizon, therefore, it is essential to develop the capacity to assess the potential performance and return of the investment in innovation projects, which will allow companies to focus their efforts on the projects with the highest expected return.

This thesis focused on the different approaches and methods used in the literature for evaluating and prioritizing projects at the early stages of innovation in a context of limited resources. An exhaustive list of different criteria and descriptors of performance was developed, establishing the foundation for the methodology for project selection here proposed, which consists on the setting, structuring and execution of the evaluation, risk analysis, resource allocation, decision and conclusions. This objective procedure involves multicriteria decision-making, deals with the risk and uncertainty in innovation and supports the construction of a portfolio of projects, therefore capturing the complexity of the problem while being simple to understand, apply and adapt to specific company needs and constraints. It can thus constitute a valuable aid for companies to build their own project selection process or to compare with the currently implemented one.

Keywords
Project selection; Innovation; Project portfolio management; Multicriteria decision-making.
1. Introduction

Innovation strengthens the growth and dynamism of all economies and, while not a goal in itself, can play a critical role in leading the world to a more sustainable growth path following the financial crisis, according to OECD’s “Innovation Strategy 2015” [1]. In companies, it is also increasingly more imperative as consumer demand becomes more sophisticated and competition more intense [2]. Consequently, companies invest in innovation to increase competitive advantage, however, despite the widespread belief that higher R&D spending translates into higher economic performance, studies show that there is no relationship between R&D spending and corporate success [3]. According to Kandybin and Kihn [4], for companies to maximize their return on innovation investment (ROI), a well-organized innovation value chain (Fig. 1) is required, mastering four critical sets of capabilities: ideation, project selection, development and commercialization.

![Fig. 1: Innovation Value Chain [4]](image)

At the start of this chain is the suggestion of several ideas and concepts that are conveyed through project proposals. However, usually only a very small fraction can be selected since resources are limited, therefore, there must be a professional method for prioritizing each potential project, just as there are systems to manage the execution stages [5] (development and commercialization) of projects. This task is complex and difficult because many options are present and resources have to be allocated considering costs, risks and benefits [6], which are often uncertain and sometimes intangible.

The project selection problem has received plenty of attention in the literature at least since the 1960s [7], [8], describing an abundant variety of approaches and models designed to support decision making in this domain and taking into account different aspects and perspectives of the problem. They have evolved from simple cost analysis to integer and linear programming to more flexible methods, such as fuzzy mathematical programming [9]. However, more recent models have tried to consider more qualitative factors involved in decision processes [10], which can easily be considered in scoring models. The books on project management by Meredith and Mantle (2009) [11] and Pinto (2010) [12] have presented various project selection models, criteria, examples and requisites for these models, among others. Sokmen [13] provides a list of the different methods and criteria used until 2013.

In what concerns the analysis of risk, typical of innovation projects, most models developed and referred in the literature rely on the determination or estimation of probability distributions to deal with uncertainty in some parameters associated with the decision, as in [11] and [14], using them to estimate the risk profiles or
probability distributions of the outcomes of the decision [11]. However, risk is also sometimes treated as criteria rather than as probabilities [6]. Ilevbare [15] presents a list of around 50 different methods and techniques for addressing uncertainty and risk.

The literature research allowed to understand the importance of project selection for the success of innovation in companies but also the challenges they face in the application of project selection models. These challenges arise because the available methods are usually too simple or excessively elaborate for most managers and companies to understand and apply systematically [7], [8]. Furthermore, it allowed to notice that some companies lack a formal selection process and, among the ones that do not, the most common mistakes that lead to ineffective portfolio management are the over-reliance on financial models and the inexistence of strategic criteria and criteria for Go/Kill decisions. It is therefore possible to conclude, as Bin et al. [8] recently pointed out, that there is still the need for additional efforts in this field, which motivated the execution of this work.

In this context, the following proposed methodology intends to deal with the complexity of the problem in a less complex way, being simple to understand, apply and adapt to the specific needs of the company. At the same time, it does not fall into the common mistakes mentioned above and approaches other areas related to the project selection problem, such as risk analysis and resource allocation.

2. Proposed methodology for project selection

The objective of this methodology is to assist companies in selecting innovation projects to be pursued, among a set of projects proposals and in a context of limited resources, which intends to capture the complexity of the problem and enable its application to different types of projects and companies. At the same time, it aims to be simple to understand, apply and adapt to the specific needs of the company. It is an objective procedure that involves multicriteria (including non-financial and intangible) decision-making, filters projects according to prerequisites and deals with risk analysis (to compute risk-adjusted scores) and resource allocation (to account for the project costs), generating valuable information in a timely and useful fashion.

This work was grounded on an extensive research of the different criteria, descriptors of performance (scaling statements) and methods used in the literature, as well as on the risk and uncertainty in innovation, the construction of a portfolio of projects, the requisites of project selection tools and the most common mistakes in these methods and in decision-making. The research resulted in an exhaustive list of different criteria and descriptors of performance found in the literature and in the methodology for project selection, which is the main contribution of this work.

This methodology is illustrated in Fig. 2 and a simple example of its application is presented afterwards. It is recommended that the application of this methodology is done by a team of decision makers, preferably formed by managers of different areas and other stakeholders, such as suppliers, clients and final users, in order to gather a large range of relevant knowledge and experience [16] and to eliminate the tendency to select projects by political means, power plays or emotion [17].
The first phase of the methodology (1), on the left, sets the evaluation process for the future project selection sessions. It consists of steps that can be executed in advance, since they do not depend on the projects but rather on the company, in order to ensure that the selection of projects is more consistent and unbiased. This task is done once and then occasionally reviewed, according to changes in the company’s objectives and situation.

The remaining parts of the methodology (2, 3, 4, 5 and 6), on the right, compose the structure of an evaluation session. Before each session, the results obtained in the first phase should be reviewed and confirmed, or adjusted to the specific situation if needed.

Fig. 2: Diagram of the project selection methodology
3. Example of application

In this chapter, an example of application of the proposed methodology for project selection is presented. It is motivated by a real application of project selection and it uses some of the real projects and includes some criteria about eco-design. The remaining information was either added or arbitrated for illustrative purposes, therefore, the intention of this example is not to highlight the projects/criteria/data but rather to demonstrate how the methodology can be applied for a project selection problem.

The real application aforementioned was conducted in the context of a PhD Thesis [18] on the innovation in SMEs (small and medium enterprises), where ideas (that is to say potential projects) were evaluated for new product/process development in Fapil, S.A., a manufacturer of domestic products, such as cleaning tools. Considering innovation and sustainability as critical success factors, eco-innovation is a strategic objective for the company, translating in the eco-design of their innovations, which focuses on the reduction of environmental impacts and efficient use of resources, also improving the brand image. For this reason, the criteria used during the project selection phase include the eco-design principles (possible solutions to improve the environmental impact of a product life cycle [19]) that correspond to the eco-design strategies (EDS) that the company pursues, among other commons ones (financial, market, strategic, intangibles, etc.).

To support the application of this methodology, namely the first three sections, the M-MACBETH software [20] is used. It applies the MACBETH approach [21], a multicriteria decision analysis method that allows to evaluate options requiring only qualitative judgements of difference in attractiveness [21]. The use of this software has three main advantages for the selection of innovation projects:

1. The qualitative nature of many of their benefits makes it difficult to score projects directly and numerically and, with MACBETH, managers can construct interval value scales based only on qualitative judgements.

2. The uncertainty associated with innovation projects and, consequently, with the predictions of their future performances, can generate hesitation in the evaluation process, which can be compensated by the possibility of choosing a sequence of qualitative categories instead of being forced to decide on just one. For instance, if the decision maker is not sure if the difference of attractiveness in a certain case is “strong” or “very strong”, or if multiple decision makers do not agree in one category, both can be chosen. Also, as the judgements are given, their consistency is verified [22].

3. It provides several types of sensitivity and robustness analyses in visual and dynamic tools, which are valuable supports for the decision makers throughout the process and at the decision stage, ensuring their trust in the constructed multicriteria model [23].

3.1. Setting the evaluation process

Tab. 1 presents some criteria that the company has identified, together with the corresponding descriptors of performance and reference levels (in bold).
Qualitative judgements of difference in attractiveness will be used to generate value-functions for the criteria in M-MACBETH, by choosing for two elements at a time (or more) of the following categories of difference in attractiveness: “no (difference)”, “very weak”, “weak”, “moderate”, “strong”, “very strong” and “extreme”. A higher/stronger category means a higher slope of the value function curve.

Fig. 3 shows the judgements matrix and value function of the criterion "Net present value", where it can be seen that the difference in attractiveness between 16000€ and 18000€ was defined as being “moderate to strong”, and then it decreases progressively, as illustrated in Fig. 3. The scores in the value functions curve can be adjusted by manually dragging the respective dots, up or down.

After constructing all value functions, the weights of the criteria will also be determined by qualitative judgements of difference in attractiveness, as presented in Fig. 4 (left). The criteria names between brackets ("Cj") represent an overall reference of the respective criteria (j). Considering that “good” and “neutral” were chosen as references, the overall reference [Cj] has a “good” performance in criterion Cj and a “neutral” performance in the remaining criteria, while [all lower] has a “neutral” performance in all criteria. Fig. 4 (right)

### Table 1: Descriptors of performance

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>More attractive</th>
<th>LEVELS OF PERFORMANCE</th>
<th>Less attractive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L1</td>
<td>L2</td>
<td>L3</td>
</tr>
<tr>
<td>C1: Production waste [g/kg of product]</td>
<td>100</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>C2: Durability [years]</td>
<td>10</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>C3: Recycling of product</td>
<td>Easily recyclable</td>
<td>Recyclable</td>
<td>Difficult to recycle</td>
</tr>
<tr>
<td>C4: NPV [Thousand Euros]</td>
<td>24</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>C5: Market size [units/year]</td>
<td>50'000</td>
<td>20'000</td>
<td>10'000</td>
</tr>
<tr>
<td>C6: Impact on image</td>
<td>Great impact</td>
<td>Good impact</td>
<td>Little impact</td>
</tr>
</tbody>
</table>
shows the resulting weights, where it can be seen that C4 (NPV) has the highest one and, together with C5 (Market size), account for almost 2/3 of the total of the weights.

3.2. Structuring the evaluation

A list of ideas (potential projects) was collected among the different stakeholders of the company [18], from which the following were selected for this example: supply chain optimization (P1), weight reduction of plastic products (P2), utilization of natural fibres (P3), utilization of biodegradable materials (P4), bi-material injection products (P5) and materials that minimize detergent utilization (P6). The company has one selection method for projects on product development and a different selection method for projects on process improvement.

For that reason, it decides to apply this methodology for the first type of projects, therefore leaving the “supply chain optimization” project out of this evaluation session. The remaining projects (P2 to P6) all passed this “project type filter”, as well as the “triage filter”, and their performances in the different criteria are shown in Fig. 5.

3.3. Project evaluation

In this stage the projects that passed the filters will finally be evaluated, i.e., they will be assigned scores accordingly to their performance on the chosen criteria (partial scores) and then their overall score will be computed by a weighted average, as presented in Fig. 6.
In order to understand the influence of the weights in the overall score, sensitivity and robustness analysis can be performed in M-MACBETH. This is a valuable tool because the values are obviously subjective, since there is always some uncertainty in the decision makers’ judgements (mainly due to the lack of information in the early stages of innovation projects).

3.4. Risk analysis

Risk will now be taken into account, expressed by the probabilities of technical (Pt) and financial (Pf) success. The overall scores (V), overall probabilities of success (P) and expected benefit (E) of the five projects are shown in Tab. 2 (white area).

<table>
<thead>
<tr>
<th>PROJECTS</th>
<th>OVERAL SCORE</th>
<th>PROBABILITY OF SUCCESS [%]</th>
<th>EXPECTED BENEFIT</th>
<th>INVESTMENT [THOUSAND €]</th>
<th>RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V</td>
<td>Pt</td>
<td>P</td>
<td>E = V*P</td>
<td>C</td>
</tr>
<tr>
<td>6</td>
<td>80,4</td>
<td>95</td>
<td>82</td>
<td>78</td>
<td>62,94</td>
</tr>
<tr>
<td>3</td>
<td>102,16</td>
<td>88</td>
<td>86</td>
<td>76</td>
<td>77,31</td>
</tr>
<tr>
<td>4</td>
<td>91,67</td>
<td>86</td>
<td>91</td>
<td>78</td>
<td>71,74</td>
</tr>
<tr>
<td>5</td>
<td>68,99</td>
<td>93</td>
<td>90</td>
<td>84</td>
<td>57,74</td>
</tr>
<tr>
<td>2</td>
<td>96,13</td>
<td>95</td>
<td>80</td>
<td>76</td>
<td>72,78</td>
</tr>
<tr>
<td>PORTFOLIO OF PROJECTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A: {6,3,4,5}</td>
<td>269,74</td>
<td>110</td>
<td>2,45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: {6,3,4,2}</td>
<td>284,78</td>
<td>120</td>
<td>2,37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C: {6,3,5,2}</td>
<td>270,78</td>
<td>115</td>
<td>2,35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D: {3,2,4}</td>
<td>221,84</td>
<td>100</td>
<td>2,22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.5. Resource allocation

The construction of a project portfolio is now proposed, where the previously calculated expected benefits (E) of the projects will be considered together with their associated investment (C). This values are present in Tab. 2 (grey area), as well as their E/C ratios and some portfolios. The common (E/C ratio) prioritization approach would result in portfolio A, while an optimization approach would result in portfolio C, which has a higher benefit for the available budget than portfolio A but has a lower E/C ratio. Nevertheless, either approach is better than a prioritization based of benefit only, which would originate portfolio D that has a much smaller benefit for the available budget and a smaller E/C ratio. Fig. 7 shows all the possible 32 (=2^5) portfolios that can be created with these five projects, where the grey line represents the efficient frontier (non-dominated portfolios) and the black dotted line represents the convex efficient frontier [24] (formed by the portfolios that have the highest benefit/investment ratio, depicted by circles).

3.6. Decision and conclusions

This evaluation session resulted in the recommendation of portfolios C or A, depending on the preference (highest E or highest E/C ratio, respectively), or portfolio B, in case the company is willing to spend an extra 5,000€. Decision makers should now discuss the robustness of these results in order to make a well-founded choice, since they will always bear responsibility for the decision [11], in addition to making a statement of the key assumptions made, the issues to be addressed in the next decision [16] and a summary of the lessons
learned in this process. Later, at the closing stage of the projects, they should compare the more recent available data with the assumptions made during the selection stage in order to identify and understand errors on the estimates and improve their project selection process.

Fig. 7: Portfolios of projects

4. Conclusion

This work allowed to understand the importance of project selection for the success of companies but also the challenges they face in the application of project selection models, as well as to identify problems that lead to ineffective portfolio management and, consequently, the need for additional efforts in this field [8]. In that context, this thesis constitutes a valuable practical contribution to the project selection field, since the proposed methodology presents a logical sequence of stages that a company should execute in order to ensure a complete, simple and transparent process of project evaluation and selection. It allowed to capture, in a less complex way, the complexity of the project selection problem, including the incorporation of risk and the construction of a portfolio of projects, without falling into the common mistakes found in the literature. The application of this methodology by companies will be a strong contribution to master their project selection capability, towards a successful innovation value chain and greater returns on investment.

There is, however, some additional development that could improve this work and strongly contribute to this field. A thorough list of all the available methods for project selection, together with their explanation, advantages and disadvantages and, when required, exemplification and application, would expedite and improve the research conducted by academics and companies, assisting them in choosing the most adequate method for each situation. In addition, it would be interesting to use and compare, in a real project selection scenario, the risk analysis here proposed against the two other common methods, namely the use of probabilities of success as criteria and the estimation of probability distributions. This would allow comparing the simplicity and practicality of the first two approaches with the sophistication and complexity of the latter.
5. References


