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# Strategic investment strategy for software companies using a multi-criteria decision analysis approach

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**Abstract** – Strategic investments are crucial for software companies as they determine the direction and growth of the businesses. Parallel to continuous improvements in information technologies, increased customer expectations, and competitive environments, deciding between new investment strategies has become even more important. Despite their prevalence, making these decisions is generally challenging, especially when there are multiple alternatives, conflicting objectives, and a group of decision-makers with different priorities. In this study, we consider this complex issue as a multi-criteria decision-making problem by focusing on a real-life case study from a software company that specializes in selling tools for online education and assessment. We propose a two-level methodology integrating the Best-Worst method (BWM) and Elimination and Choice Translating Reality (ELECTRE-III). In the first step, six criteria that play a role in software investment decisions are defined based on an extensive literature review and expert interviews. Then a group of experts compared these criteria by using BWM, and importance weights were calculated. In the third step, the ELECTRE-III method is utilized to evaluate a set of investment alternatives and provide a ranking. We conclude with insights for both researchers and practitioners who are concerned about strategic investment decisions.

**Keywords:** Strategic investment; multi-criteria decision-making (MCDM); Best-Worst Method; ELECTRE

## 1. Introduction

As defined by Cardon et al. (2013), "being an entrepreneur" means "embarking on proactive and aggressive initiatives to alter the competitive scene to their advantage". The focus is on three distinct roles: (1) developing new products or services; (2) founding new organizations, or (3) developing organizations beyond their initial successes. This study is related to role number 1: developing new products or services. Providing customers with up-to-date products and services is crucial not only for competitiveness but also for the long-term market shares of the businesses. This is even more important for software companies where the product life cycles are quite short, customer expectations are high, and the competition is fierce. Therefore decisions regarding investment strategies should be made carefully by considering various parameters from different perspectives. Since new investments are long-term, multi-layered strategical decisions, they may affect many departments and stakeholders. For instance, new investments in an innovative product or solution may directly impact market shares and sales, affecting the company's marketing and finance strategies. From a similar point of view, there is a special relationship between strategic investment decisions and supply chain management activities (Burkhardt, 2019). Investments in new products or technologies may affect the infrastructure of the current supply chains from many aspects, such as the location of data centres, distribution points, and server networks. In addition, when it comes to software technologies, there is also a digital supply chain that includes various systems like licenses, subscriptions, or customer networks (Buyukozkan & Gocer, 2018). When something changes in the software

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system, all these supply chain components should be reconsidered and revised. Therefore, the new investment decisions should also be considered from a supply chain perspective if the company aims to maintain sustainable, long-term strategies.

It is a known fact that new investment strategies are very complex problems with conflicting objectives, and it is challenging to satisfy all desires. For example, if a company wants to maximize the innovation level of a new product, the goal of minimizing the total cost may need to be compromised. Furthermore, there is often more than one department, like marketing, finance, and manufacturing, that has been affected by the new product investment decisions. Their expectations and needs should be considered to maintain the feasibility of the strategy that will be chosen. While the marketing department focuses on price and ease of use, the management team may prioritize the originality of the product. For these reasons, proper tools and systematic approaches should be utilized to ensure the integrity of new investment decisions. Among many decision-making tools, Multi-Criteria Decision-Analysis (MCDA) methods have frequently been preferred for complex strategic decisions since they are convenient for considering conflicting objectives to evaluate a set of alternatives (Keeney & Raiffa, 1975).

MCDA addresses the issue of assisting decision-makers in selecting, ranking, or sorting a set of alternatives based on a number of criteria (Valls & Torra, 2000). Most of the proposed methods follow a similar procedure: setting the alternatives and objectives, defining the performance measures (attributes) for each objective, evaluating the alternatives on these attributes and eliciting values over them, and calculating the attribute weights and aggregation (Keeney & Raiffa, 1975). As can be seen from the given steps, solving a structured problem consists of two significant stages: finding out the importance (weights) of each defined criterion and ranking the alternatives based on their associated values. For both parts, multiple tools have been introduced in the literature, such as Analytic Hierarchy Process (AHP), SMART, Swing, Best-Worst Method, TOPSIS, PROMETHEE, and ELECTRE family. Ranking and choosing software projects is a common but frequently challenging process that typically involves more than one decision-maker and more than one dimension for evaluating the possible impacts. For this reason, the methods to be used should be chosen carefully, taking into account the characteristics of the problem and the dynamics of the evaluation process.

MCDA methods are already widely used for complex strategic decisions to obtain a ranking of different choices based on various criteria. In this study, we introduce a combination of the Best-Worst Method and ELECTRE III, which has not been applied to strategic investment decisions to our best knowledge. First, the importance weights of the criteria are derived by using Linear BWM. BWM provides a simple application procedure for decision-makers, so it can easily be understood and applied. Despite this practicality, the BWM method is proven to result in more consistent pairwise comparisons than other methods (Rezaei, 2020). In addition to these advantages, the recent empirical findings stated that BWM performs better than many MCDA methods in terms of cognitive biases such as anchoring (Rezaei et al., 2022) and equalizing bias (Rezaei et al., 2022). This means the judgments of decision-makers are less affected by the method, and evaluations are more reliable. Thanks to these consistent and reliable calculations, the attribute weights can be used as reliable intrinsic weights in the ELECTRE-III method (Makarevic & Stavrou, 2022). In the second step of the proposed methodology, investment alternatives are ranked by ELECTRE-III, considering their performance on the attributes. ELECTRE-III is a robust and flexible method that can handle a large number of alternatives and attributes. One of the strengths of ELECTRE III is its use of indifference, preference, and veto thresholds, which enables the decision-makers to incorporate their psychological components into the analysis. Also, its non-compensatory nature is another advantage in strategic decision-making problems such as software investments. In summary, this paper makes the following contributions:

- A hybrid decision-making approach is proposed based on BWM and ELECTRE III.
- Literature review and expert interviews provide insights into software investments and strategic decisions from theoretical and practical perspectives.
- The proposed method can be used in similar strategic investment problems by revising the attributes.
- It presents recommendations and knowledge transfer by considering the findings of a real-world case study.

The remainder of this article is structured as follows. Section 2 presents a literature review, followed by the methodology in Section 3. Sections 4 and 5 are devoted to our real-world application in a software company. The conclusion of the research, the lessons that can be taken from the study, and future directions are summarized in Section 6.

## 2. Literature Review

There is no single answer to the problem of software investment decision-making. Therefore, all aspects should be carefully considered before making decisions that could result in financial losses or mediocre results. The challenge is made more difficult by the fact that software science does not lend itself to mass-production methods (Bernstein, 1997). The industry does not agree on where the greatest return on investment can be achieved or what is the best strategy for finding the best alternative (Bernstein, 1997). In alignment with these disagreements, many studies focus on strategic investment decision problems from various perspectives in the literature. For example, Rosenzweig and Volarević (2010) define the optimal performance of a new investment decision by formulating it as a multi-criteria decision problem. They identify nine criteria to measure the performance of investment alternatives, and based on the utility functions of each criterion, they optimize the performance of each project. In alignment with the performance maximization objective, their criteria set mainly consists of internal factors such as the net present value, internal rate of return, or cash flows of the company. However, as much as internal factors like risks of the investment alternatives or their expected returns, there are also external factors that play a role in the new investment problems. Consideration should be given to the setting in which the decision is made and its various effects on the criteria. For example, Bialowolski and Weziak-Bialowolska (2014) studied some of these external factors for Polish companies. In their study, considering the size of companies from the different branches, the relationships between external factors and investment decisions are studied. Their survey, which takes into account criteria such as tax policies, environmental regulations, and legal barriers, defined payment delays as a major problem in investment decisions. In addition, law-related problems and macroeconomic factors are found as the most influential factors in new investment decisions of Polish companies. Another study that also considers the size of companies was conducted by Chatzipetrou et al. (2018), who concluded that the type of organization affects how important certain criteria are. Smaller businesses with less developed products place more emphasis on features related to the ease of use, development, and maintenance of the product. Larger companies with more developed products place more emphasis on characteristics related to cost. Bereketli and Genevois (2013) researched improvement strategies in product development. They defined a list of stakeholder requirements that are important to consider in the decision-making process. One of these requirements was ease of use, which was also highlighted as important by Chatzipetrou et al. (2018). They also refer to cost as a very important criterion in the new product strategies. Similarly, Espie et al. (2000) focus on investment strategies for companies. The criteria they argued as important were rather similar to the ones mentioned by the authors discussed. The criteria they mentioned were costs, reduction in customer effort due to the innovation – which can be related to the level of innovation –, and the number of failures expected as a result of implementing the innovation – which can be related to the ease of use. From a slightly different perspective, Alshaibi et al. (2016) propose a method with Analytic Hierarchy Process (AHP) that uses non-financial parameters for strategic investment decisions. In this study, instead of using financial parameters to evaluate the new investment alternatives, decision-makers focus on the company. Parameters like information policies, safety-related issues, energy, environmental impact, and social performance are analyzed using AHP. An application is presented with the motivation of providing a comprehensive non-financial measurement tool for strategic investment problems.

An important issue that should be considered while making a strategic investment decision is the trade-off between short- and long-term returns on investments. Although making these time trade-offs is important when making the decision to invest in the development of certain products over others, it is not an easy task (Withey, 1996). Furthermore, Erdogmus et al. (2004) argue that the term return on investment is still too undefined and ambiguous to be used in investment strategies, specifically for software. Since new investment decisions are very complex and require foreseeing future outcomes, there is always an uncertainty factor that should be considered. The role of investment risk in decision-making is discussed by Virlics (2013) considering two main sets of factors: (I) an objective, timely study of the investment, its potential outcomes, and its estimated reward; and (II) the investor's subjective perspective. Depending on the sector, investments come with either smaller or larger risks. Risk and uncertainty are subjectively experienced and entail emotional and psychological components. Authors conclude that the method which aims to structure the investment strategy decision-making process, must take into account this phenomenon of subjective risk and integrates parameters to ensure their representativeness.

Another important sub-field of software investment decision-making literature is the reusing of software. Rine and Sonnemann (1998) argue that investment strategies are one of the key factors influencing the software reuse level, which in its turn influences the productivity and quality of software products. They define a wide range of criteria set that measure the success of the reuse capability of software systems. Parallel to Virlic's (2013) findings about the risk perception of the decision-makers in the new investment problem, this research highlights the importance of the perceived re-usability potential of the software in the eyes of individuals. In another study, Favaro et al. (1998) studied the software reuse investment problem by comparing three techniques: Net Present Value, Decision Tree Analysis, and Contingent Claims Analysis. Their application which includes many parameters such as risk, returns, and cash flows, shows that among these three techniques, Contingent Claims Analysis is the most promising one for capability and perspective on strategic investment problems. In addition, they draw attention to the complexity of strategic decision problems and warn practitioners about choosing the options and methods carefully.

Based on the literature review findings, it can be said that new investment decisions are highly important complex problems and should be studied carefully. In spite of many applications with various methods, there are still many unresolved complex problems in the literature around software investment strategies specifically, and investment strategies in general. This study aims to focus on this gap by taking advantage of the flexibility and reliability of two multi-criteria decision-making methods and applying a real-life case study to discuss the issue from a practical point of view.

## 3. Methodology

As stated in the literature review section, investment strategy selection is a complex MCDA problem and requires a systematic solution. We propose a four-level methodology with two MCDA methods to solve this problem, as illustrated in Figure 1. The first stage is identifying the context of the decision analysis, and it includes analyzing and structuring the problem and defining the criteria. In the second step, specified criteria are evaluated and weighted by applying the Best-Worst Method. Using these calculated importance weights as input, alternatives are ranked using the ELECTRE III method in the third step. Finally, the fourth step is analyzing the findings and discussing them in the context of the decision problem. The details of the steps and methods are presented in the following subsections.

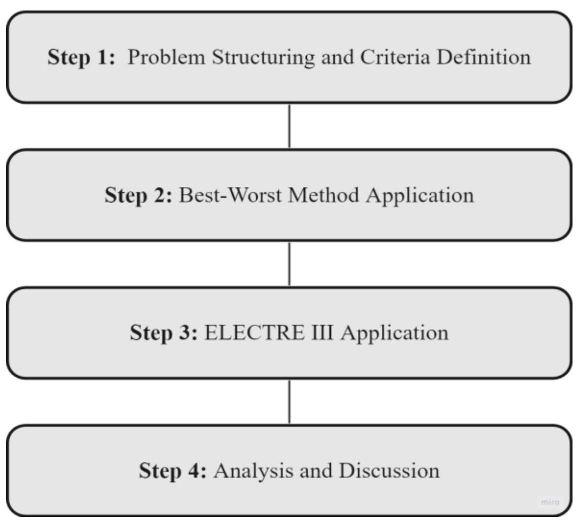


Figure 1. The steps of the proposed methodology.

### 3.1 Problem structuring and criteria definition

The first step of MCDA is structuring the problem and defining the objectives. Later, the representative criteria should be identified to measure the performance of the alternatives. In this study, the main objective is to rank the software investment strategies with respect to a set of criteria. With this motivation, after an extensive literature review and expert interviews, six criteria were selected, as can be seen in Table 1.

Table 1. Criteria set and corresponding studies from the literature.

| Criteria | Sources |
|---|---|
| Cost | Chatzipetrou et al. (2018), Bereketli and Genevois (2013), Espie et al. (2000) |
| Level of off-the-shelf fit to the product | Chatzipetrou et al. (2018). |
| Level of support for the development | Baykasoğlu et al. (2017), Kristensson et al. (2008) |
| Ease of use | Chatzipetrou et al. (2018), Bereketli and Genevois (2013), Espie et al. (2000) |
| Level of innovation | Chatzipetrou et al. (2018), Baykasoğlu et al. (2017), Espie et al. (2000) |
| Level of maintenance needed | Chatzipetrou et al. (2018) |

**Costs [Euros]:** As in many decisions, cost plays a significant role in strategic investment decisions, too (Chatzipetrou et al., 2018). In this study, the cost criterion represents all expenses related to new software development, such as infrastructure investments, licensing fees, development costs, maintenance, and the number of hours needed to develop the functionality times an hourly wage. It is measured by Euro.
**Level of off-the-shelf fit to the product [1-10]:** This criterion measures the extent to which the alternative software considered for new investment meets the company's particular needs. It is essential to see the suitability of the possible software with the existing infrastructures and strategic objectives. Also, it considers whether a product is suitable for the coming years to be sold and, thus, provides inputs on whether or not a product is considered future-proof.
**Level of support for the development (number of requests) [1-10]:** It is a known fact that customer involvement is crucial, especially when providing them with new technologies and expecting to change their previous preferences (Baykasoğlu et al., 2017). Adequate customer involvement ensures valuable feedback from end-users, higher satisfaction levels, and an easier implementation process. Therefore, the level of support for the development is found to be a necessary criterion.
**Ease of use [1-10]:** Software alternatives should be user-friendly and easy to navigate as much as possible. In order to prevent customer resistance and enhance user adaptation and satisfaction, the new investment decisions should consider ease of use as a criterion.
**Level of innovation [1-10]:** This criterion measures the innovation levels of new investment strategies by considering two sub-components: the radicality of the innovation and the level of new knowledge contained, as suggested by (Baykasoğlu et al., 2017). It has been shown that products that result from radical innovations are more easily differentiated from other products in the market. A new product should contain a high level of knowledge and provide users with innovative solutions.
**Level of maintenance needed [1-10]:** Software requires constant maintenance and updates to ensure performance and safety. While deciding between new investment alternatives, it is essential to consider these long-term efforts and resource needs. Alternatives that have a low level of maintenance needs cause less interruption and financial troubles.

### 3.2 Best-Worst Method

Best-Worst Method is a multicriteria decision-making method that requires fewer pairwise comparisons compared to many similar methods, such as AHP (Rezaei, 2015). BWM has the advantage of practicality and easy applicability, and therefore it has attracted great attention in recent years. It also provides decision-makers with consistent results and less vulnerable evaluations to systematic errors (Rezaei, 2022). The steps of BWM are given in the following.

**Step 1:** The set of decision criteria $\{c_1, c_2, \dots, c_m\}$ is defined for evaluating the alternatives.
**Step 2:** The decision-maker identifies the best and the worst criterion from the set of criteria.
**Step 3:** The decision-maker decides the degree of preference of the best-chosen criterion over all the other criteria. The preference is indicated with a number in the range of 1 to 9. A Best-to-Others vector of decision-maker indicates this reference $A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$ where $a_{Bj}$ illustrates the preference of the best criterion B over criterion $j$.

**Step 4:** The decision-maker decides the degree of preference of all other criteria over the Worst criterion. The preference is indicated with a number in the range of 1 to 9. A preference close to 1 indicates a small preference for a criterion $j$ over the Worst criterion $W$. Others-to-Worst vector indicates this preference $A_W = (a_{1W}, a_{2W}, \dots, a_{nW})$ where $a_{jW}$ shows the preference of criterion $j$ over the Worst criterion W.

**Step 5:** The optimal criteria weights, $w_j^*$ are calculated considering the following requirements:

For each pair of $\frac{w_B}{w_j}$ and $\frac{w_j}{w_W}$, the ideal solution is where $\frac{w_B}{w_j} = a_{Bj}$ and $\frac{w_j}{w_W} = a_{jw}$. A solution should be found to minimize the maximum absolute differences $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jw}\right|$ for all $j$ to satisfy the conditions. Under the non-negativity and unit-sum conditions for weights, the following linear model is obtained (Rezaei, 2016).

$$\min \xi$$
$$\text{s.t.}$$
$$\begin{aligned} \left|w_B - a_{Bj} w_j\right| &\le \xi, for\ all\ j, \\ \left|w_j - a_{jW} w_W\right| &\le \xi, for\ all\ j, \\ \sum_j w_j &= 1 \\ w_j &\ge 0, \text{for all } j \end{aligned} \tag{1}$$

The optimal weights $w_j^*$ and $\xi^*$ can be obtained by solving this model.

**Step 6:** The consistency is checked for each decision-maker by using input-based consistency formula as given by Liang et.al. (2020).

$$CR^I = max_j CR^I{}_j \tag{2}$$

where,

$$CR^I{}_j = \frac{\left|a_{Bj} \times a_{jW} - a_{BW}\right|}{a_{BW} \times a_{BW} - a_{BW}}, a_{BW} > 1 \tag{3}$$

$$CR^I{}_j = 0, a_{BW} = 1 \tag{4}$$

The corresponding thresholds are considered as in the study by Liang et al. (2020).

### 3.3 ELECTRE III

ELECTRE III is a member of a family of outranking methods which was introduced by Bernard Roy for systematically ranking the alternatives with respect to multi-criteria (Figueira et al., 2016). It is a non-compensatory method meaning that if an alternative performs poorly on one criterion, it cannot be compensated by excelling on another criterion. This is maintained by preference thresholds that are defined by the decision-maker. If an alternative cannot achieve the minimum acceptable level of performance on a criterion, it is considered non-acceptable, regardless of its performance on other criteria. By doing so, ELECTRE provides an accurate representation of preferences. In addition, compared to previous versions, ELECTRE III is a more interactive method and provides preference/indifference thresholds. It also has the advantage of considering qualitative and quantitative criteria at different levels of ambiguity (Hashemi et al., 2016). The steps of ELECTRE III are presented in the following.

**Step 1:** Decision makers define their preference ($p_j$), indifference ($q_j$) and veto ($v_j$) thresholds. If there is more than one decision maker, their values are aggregated.

**Step 2:** The concordance index $c_j(a,b)$ is computed for each pair of alternatives $a$ and $b$. The comparison indices are determined via one of the following cases:

$$C(a,b) = \frac{1}{W}\sum_{j=1}^{n} w_j c_j(a,b) \tag{5}$$

$$W = \sum_{j=1}^{n} w_j \tag{6}$$

$C(a,b)$ holds a value between 0 and 1. If alternative $a$ is worse than alternative $b$ with respect to all criteria, it takes 0. The comparison indices are determined via one of the following cases:

***Case 1:*** If alternative $a$ is equivalent to or better than alternative $b$ minus indifferent threshold for criterion $j$:

$$c_j(a,b) = 1, \text{ if } g_j(a) + q_j\left(g_j(a)\right) \geq g_j(b) \tag{7}$$

where $g_j(i)$ represents the performance of alternative $i$ with respect to criterion $j$.

***Case 2****:* If sum of the performance threshold and the performance of alternative $a$ is less than the performance of alternative $b$ with respect to selected criterion:

$$c_j(a,b) = 0 \text{ if } g_j(a) + p_j\left(g_j(a)\right) \leq g_j(b) \tag{8}$$

***Case 3****:* In all other cases:

$$c_j(a,b) = \frac{g_j(a) - g_j(b) + p_j\left(g_j(a)\right)}{p_j\left(g_j(a)\right) - q_j\left(g_j(a)\right)} \tag{9}$$

Note that for criteria like the cost criterion, the higher the value, the worse the preference. Then, the $g_j(a)$ and $g_j(b)$ are switched in the formulas.

**Step 3:** The discordance index $D_j(a,b)$ is computed for each pair of alternatives $a$ and $b$. The discordance index reflects situations in which alternative $a$ is better than alternative $b$ generally, but worse in specific situations. The discordance index needs to be determined via one of the following cases:

***Case 1:*** If alternative $b$ is not better than alternative $a$ by a more than veto threshold, $v_j$.

$$D_j(a,b) = 1, \text{ if } g_j(b) \geq g_j(a) + v_j\left(g_j(a)\right) \tag{10}$$

***Case 2:*** If alternative $b$ is better than alternative $a$ by more than veto threshold, $v_j$.

$$D_j(a,b) = 0, \text{ if } g_j(b) \leq g_j(a) + p_j\left(g_j(a)\right) \tag{11}$$

***Case 3:*** For all other cases:

$$D_j(a,b) = \frac{g_j(b) - g_j(a) - p_j\left(g_j(a)\right)}{v_j\left(g_j(a)\right) - p_j\left(g_j(a)\right)} \tag{12}$$

**Step 4:** By combining the results of concordance and discordance calculations, the credibility (S(a,b)) is computed and there are two cases as in the following:

***Case 1:*** If there is not discordance or veto threshold:

$$S(a,b) = C(a,b) \; if \; D_j(a,b) \leq \; C(a,b), \forall_j \tag{13}$$

***Case 2:*** In all other cases:

$$S(a,b) = C(a,b)\prod_{j=1}^{n}\frac{1-D_j(a,b)}{1-C(a,b)} \tag{14}$$

**Step 5:** Considering the performance of the alternatives in the previous steps, the final ranking is computed. Whenever alternative $a$ outranks alternative $b$, gets $a+1$ while alternative $b$ gets $a-1$. A final score and ranking are determined by adding all the scores.

## 4. A real-world application

This section presents a real-world application that is based on a software company. This company sells an online assessment tool for digital as well as handwritten assignments. Digital tests can be constructed and taken online. With the help of several question types and functionalities, the tests can be made as extensive as desired. The handwritten assignments can be constructed online, printed for an offline taking session, and finally scanned and uploaded to the platform again. This enables teachers to grade together and publish the results online. For both assignment types, specific functionalities are developed to help the teachers improve their assignments. The company's software is used in several countries over the world and the platform is used by universities, schools, and companies. Furthermore, they integrate with several partner platforms to make the product as complete as possible.

The developments are based on two types. The first type of development is bug fixes and improvements to the platform. The second type of development is new functionalities. Each year, decision-makers of the company need to decide which new functionalities they want to develop for the platform. Investments are needed to develop new functionalities, so the decision-makers have to come to an agreement. For upcoming investments, the company has narrowed their options down to four investment alternatives. Each alternative is focused on the development of a different asset of the platform. These alternatives are referred to as Alternative A, Alternative B, Alternative C, and Alternative D because of the confidentiality policy of the company. Alternative A capitalizes on developments in formative testing. Alternative B has to do with new functionalities regarding coding assignments. Alternative C relates to converting handwritten to digital text using artificial intelligence. Finally, alternative D focuses on comparing answers given to discover and indicate similarities. As the team of decision-makers, all have different roles within the company, it is realistic to expect different standpoints from these decision-makers. Within the software company, a distinction is made between a team that focuses on developing new functionalities and a team that focuses on improving and fixing bugs in existing functionalities. For the first team, the product team, a roadmap is used as a guideline for which functionalities will be developed during the year. The roadmap consists of several small developments and one or a few relatively large developments. At the end of the year, the decision needs to be made on which large development should be included in the roadmap. Several factors are taken into account to make this decision. Due to the different interests of the decision-makers, the investment decision is hard to make. Several criteria are determined on which the alternatives are reviewed as shown in Table 1.

The goal of the software company, different criteria and alternatives are visualized in a decision tree, Figure 2. This decision tree shows the other options that can be chosen for the goal.

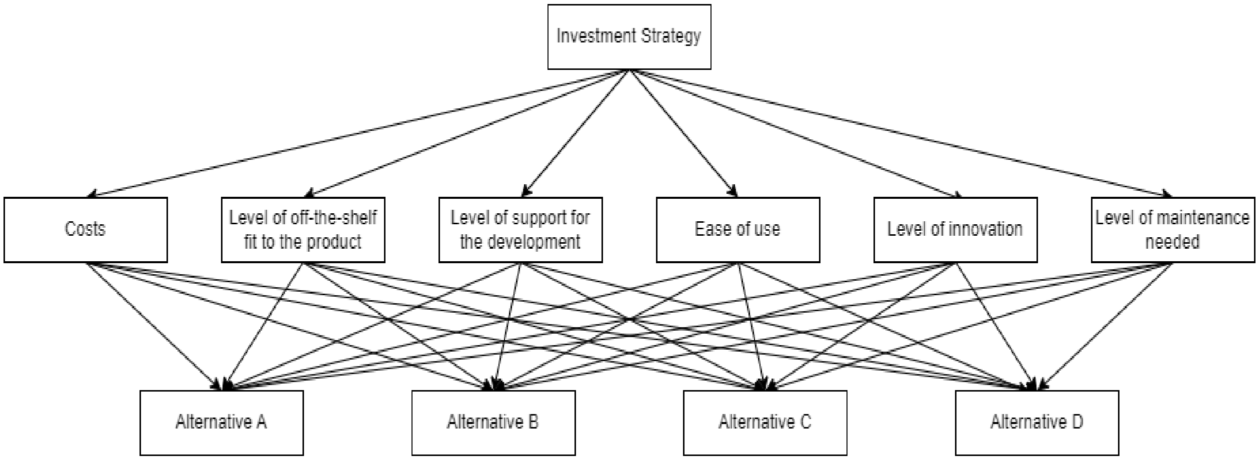


Figure 2. Decision tree of the software company investment problem.

The four interviews were conducted with the four decision-makers of the company on the 27th of October 2022. The CEO, CFO/CTO, CCO, and COO were interviewed. The interview consisted of two parts:

1. Questions about the relative importance of the defined criteria (BWM step)
2. Questions about their indifference ($q$), preference ($p$), and veto ($v$) values (ELECTRE step)

To determine the preference, each decision maker is interviewed and asked questions that should be answered using the 1-9 evaluation scale (Saaty, 2004). These interviews resulted in a set of weights for each criterion per decision maker. These weights were then aggregated using the geometric mean and final weights are obtained.

## 5. Application results

This section presents the application results of the real-life case study. First, the findings of BWM are given, and later ELECTRE is presented.

### 5.1. Weighing the criteria using BWM

The set of criteria equals Costs ($c_1$), Level of off-the-shelf fit to the product ($c_2$), Level of support for the development ($c_3$), Ease of use ($c_4$), Level of innovation ($c_5$) and Level of maintenance needed ($c_6$). Data of the different alternatives are combined in a performance matrix as tabulated in Table 2. In this matrix, values are assigned to the criteria per alternative. Different relations can be assigned to the criteria. For example, the lower the costs, the better this alternative will score. But, the higher the level of off-the-shelf fit to the product the better this alternative will score. These relations are taken into account.

Table 2. Performance matrix.

| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ |
|---|---|---|---|---|---|---|
| ***Alt. A*** | 80.000 | 5 | 5 | 2 | 5 | 4 |
| ***Alt. B*** | 40.000 | 3 | 2 | 4 | 1 | 3 |
| ***Alt. C*** | 65.000 | 2 | 2 | 3 | 5 | 5 |
| ***Alt. D*** | 55.000 | 4 | 4 | 5 | 3 | 3 |

The best and worst criterion for each decision-maker are stated in Table 3. The best criterion is indicated with a 1 in the "Best to Others"-row of a decision-maker. The worst criterion is indicated with a 1 in the "Others to Worst"-row of a decision-maker.

Table 3. Best to others & Others to Worst values.

| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ |
|---|---|---|---|---|---|---|
| DM 1 - Best to Others | 2 | 1 | 6 | 4 | 5 | 8 |
| DM 1 - Others to Worst | 7 | 8 | 4 | 5 | 3 | 1 |
| DM 2 - Best to Others | 1 | 5 | 9 | 2 | 6 | 3 |
| DM 2 - Others to Worst | 9 | 4 | 1 | 8 | 3 | 7 |
| DM 3 - Best to Others | 6 | 4 | 2 | 1 | 3 | 9 |
| DM 3 - Others to Worst | 3 | 6 | 8 | 9 | 7 | 1 |
| DM 4 - Best to Others | 4 | 1 | 6 | 2 | 5 | 9 |
| DM 4 - Others to Worst | 6 | 9 | 4 | 8 | 5 | 1 |
| **Normalized weights** | **0.2043** | **0.2426** | **0.1005** | **0.2685** | **0.1225** | **0.0616** |

The importance weights are calculated based on the Best to Others and Others to Worst evaluation matrices in Table 3. After aggregating the individual weights and normalization, the most important criterion is found as Ease of use. Also, the level of off-shelf-fit to the product criterion is the second most important criterion. The level of maintenance needed is the least important criterion for new investment decisions.

In addition, the consistency check is done for each pairwise comparison. The answers of all decision-makers given in the interviews were reliable and had acceptable consistency levels. Table 4 illustrates calculated input-based consistency ratios and associated thresholds.

Table 4. Consistency-ratio check.

| | **Input-Based Consistency-Ratio** | **Associated Threshold** |
|---|---|---|
| ***DM 1*** | 0.2857 | 0.3154 |
| ***DM 2*** | 0.2321 | 0.3154 |
| ***DM 3*** | 0.2083 | 0.3337 |
| ***DM 4*** | 0.3036 | 0.3154 |

## 5.2 Ranking the alternatives using ELECTRE III

After calculating the importance weights of criteria, we use them as intrinsic weights in ELECTRE and compare four software development alternatives. Based on the interviews with experts, data of the indifference, preference, and veto values of all decision-makers are reported in Table 5. The indifference, preference, and veto values of the different decision-makers are aggregated in order to have one value per criterion.

Table 5. Indifference, preference, veto values.

| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ |
|---|---|---|---|---|---|---|
| **Indifference values** | | | | | | |
| DM 1 | 2750 | 1 | 3 | 2 | 1 | 3 |
| DM 2 | 2500 | 2 | 3 | 1 | 3 | 1 |
| DM 3 | 3000 | 2 | 1 | 1 | 2 | 4 |
| DM 4 | 3000 | 1 | 2 | 1 | 2 | 4 |
| **Preference values** | | | | | | |
| DM 1 | 5000 | 2 | 4 | 3 | 3 | 5 |
| DM 2 | 5000 | 4 | 4 | 2 | 5 | 3 |
| DM 3 | 10000 | 4 | 3 | 2 | 3 | 6 |
| DM 4 | 7500 | 2 | 3 | 2 | 3 | 6 |
| **Veto values** | | | | | | |
| DM 1 | 25000 | 5 | 7 | 6 | 7 | 9 |
| DM 2 | 20000 | 7 | 10 | 5 | 8 | 5 |
| DM 3 | 35000 | 8 | 5 | 5 | 7 | 10 |
| DM 4 | 30000 | 5 | 7 | 6 | 7 | 9 |

After defining all these threshold values, comparison indices are computed for all pairs of alternatives per criterion. Then, the comparison indices are weighted based on their importance, Table 6.

Table 6. Weighted concordance matrix.

| | Alt. A | Alt. B | Alt. C | Alt. D |
|---|---|---|---|---|
| **Alt. A** | 1 | 0.54 | 0.80 | 0.52 |
| **Alt. B** | 0.53 | 1 | 0.88 | 0.91 |
| **Alt. C** | 0.69 | 0.28 | 1 | 0.25 |
| **Alt. D** | 0.78 | 0.80 | 0.91 | 1 |

The discordance indices are determined based on one of the three cases and the maximum discordance index is determined per set of alternatives as illustrated in Table 7.

Table 7. Maximum discordance matrix.

| | Alt. A | Alt. B | Alt. C | Alt. D |
|---|---|---|---|---|
| **Alt. A** | 0 | 1 | 0.41 | 0.91 |
| **Alt. B** | 0.94 | 0 | 0.68 | 0 |
| **Alt. C** | 0.96 | 0.91 | 0 | 0.36 |
| **Alt. D** | 0.15 | 0.41 | 0 | 0 |

The credibility matrix is set up based on the weighted concordance and maximum discordance matrices Table 8.

Table 8. Credibility matrix.

| | Alt. A | Alt. B | Alt. C | Alt. D |
|---|---|---|---|---|
| **Alt. A** | 1 | 0 | 0.80 | 0.10 |
| **Alt. B** | 0.07 | 1 | 0.88 | 0.91 |
| **Alt. C** | 0.08 | 0.04 | 1 | 0.21 |
| **Alt. D** | 0.78 | 0.80 | 0.91 | 1 |

All values from the credibility matrix are reviewed based on the cut-off level value which is chosen as $\lambda = 0.7$ in this study. The reviewed values are added to the cut-off matrix as can be seen from Table 9.

Table 9. Cut-off matrix.

| | Alt. A | Alt. B | Alt. C | Alt. D |
|---|---|---|---|---|
| **Alt. A** | 1 | 0 | 1 | 0 |
| **Alt. B** | 0 | 1 | 1 | 1 |
| **Alt. C** | 0 | 0 | 1 | 0 |
| **Alt. D** | 1 | 1 | 1 | 1 |

The qualification consists of two values, a summation of the row ($W_i$) and a summation of the column ($S_i$). The alternatives are ranked based on the qualification level in Table 10. The higher the qualification level, the higher the rank.

Table 10. Qualification and ranking matrix.

| Alternative | *W* | *S* | Qualifications | Rank |
|---|---|---|---|---|
| **Alt. A** | 2 | 2 | 0 | 3 |
| **Alt. B** | 3 | 2 | 1 | 2 |
| **Alt. C** | 1 | 4 | -3 | 4 |
| **Alt. D** | 4 | 2 | 2 | 1 |

As can be seen Alternative D is ranked first. This means the company should invest in comparing answers to detect plagiarism. This aligns with the current trend where online education is playing an increasingly important role. Alternative B comes second in the test and the reason can be found in the fact that digitalization is still on the rise. Coding is becoming a basic part of education and so this needs to be addressed. Alternative A comes in at spot three and this can be traced to the new way of testing where students' progress is tracked. Finally, alternative c has to do with handwritten tests. Given the transition from handwritten to digital testing, this alternative is not of high interest.

## 6. Conclusion and Future Research

In this study, we focused on strategic investment decisions and presented a case study for a software company. Two-level MCDA approach including BWM and ELECTRE is structured and applied. Four experts from a software company took part as decision-makers and evaluated the investment alternatives for the coming year. The application results have shown that while investing in a new software feature ease of use is the most important criterion for the company. This finding is in parallel to the findings of (Chatzipetrou et al., 2017), (Bereketli & Genevois., 2013) and (Espie.,2000) since they pointed ease of use as an important factor in software decisions. Since this was a group decision-making application, preference differences are obtained. For instance, the CFO found costs most important, whereas the COO found the ease of use most important. This example supports the fact that while making strategic decisions, depending on their roles preferences of decision-makers might deviate and a systematic decision-making strategy should be applied properly. The level of maintenance is found as the least important criterion. Various reasons can be given to this. For instance, if the company has an internal department for maintenance, they may consider it less important since they easily can solve the problems. Similarly, if the new alternatives have a guarantee, maintenance may not be an issue for the company. When it comes to the alternative evaluation, the alternative ranked 1 (Alt D) scored highest on the most important criterion, and the alternative ranked 2 (Alt B) scored second highest. Alt D showed average performance in most criteria. Only for the most important criterion, ease of use, it scored highest. These outcomes are, therefore, also corresponding to expectations. The results show the aggregated decision makers' preference to invest in Alternative D as a new innovation project. This finding aligns with current developments regarding online education. A direct consequence of this is assignments that also have to be made online, where checking the originality of the work is more difficult as there is no live monitoring of input and any use of external sources. The results were also discussed with the decision-makers. They showed satisfaction with the outcomes. One thing that was discussed due to the outcomes, was the possibility of giving the company's founder more influence in the decision-making. It is argued that, when push comes to shove, the company's founder eventually decides on investments. Thus, it might have been more realistic to use a hierarchical structure by giving the founder's preferences more weight compared to the other decision-makers.

Social interaction between the interviewees before the interviews with respect to investment strategies, which could be a threat to internal validity, was avoided. However, there is a fair amount of validity uncertainty with regard to the performance matrix, as five out of the six criteria had measurement uncertainty due to the usage of levels that had to be determined intuitively. By engaging in a thorough dialogue with the decision-makers and supporting the decisions with the relevant literature, it was hoped to minimize this.

Several limitations are linked to this study. First, it is assumed that all decision-makers have equal influence on the final decision of the investment problem, but often one or more decision-makers have more influence than others. Second, the ranking should be discussed first before making the final decision. The preference of decision-makers can change during the determination of the ranking and due to the preference of other decision-makers. Third, during the data collection and further calculations, it might be that certain criteria come up to be relevant to include in the research, which might have been initially left out.

For future research, a hierarchical structure for the BWM method can be taken into account in order to take the difference of influence of the different decision-makers into account. Also, the number of criteria can be increased for a more comprehensive evaluation. Furthermore, the approach described can be changed into an iterative process that enables decision-makers to adjust their preferences. Discussions between the decision-makers based on the outcomes can result in an adjustment of preference. Based on the adjustments, the ranking can be re-constructed. This iterative process can result in a better fit. This iterative process gives the possibility to include or adjust criteria when changes are preferred.

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