Project Idea Selection in an Automotive R&D Center

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Abstract. R&D project selection is one of the most important issues for an R&D center. Evaluating more than one project in terms of different criteria, selecting and implementing the most appropriate project is very critical for both the company's profit and the sustainability of the project. The project selection process is handled by different processes in companies. Due to the importance of this issue, companies adopt a selection process in line with their own strategies. In this study, an application was carried out with the fuzzy TOPSIS method to evaluate alternative project ideas that will be an R&D project in the R&D center of an automotive company. 4 different criteria were evaluated by experts for 6 different project ideas. With the implementation realized as a result of expert evaluations, a priority order was obtained for 6 project ideas. In practice, as a result of the evaluation, the alternative project P5 with the highest value in the ranking is selected as the next R&D project to be started.

Keywords: Project selection · fuzzy TOPSIS · R&D · automotive

1 Introduction

Nowadays, large-scale companies should attach importance to R&D activities in order to achieve growth in market shares and to be a leading company by following the agenda in line with the dynamics of the sector in which they operate [1]. While determining the strategies of the companies, it is very important to ensure the right distribution of resources, especially in terms of labor and financial resources, to the right projects [2]. In order to make this evaluation correctly, the company must analyze the resources it has correctly, evaluate the details of alternative projects correctly, and then make choices among these alternatives, taking into account the available resources. R&D project selection and financing decisions are critical for the firm [2].

The difficult part in these elections; ensuring that the organization chooses projects that will lead it to success, projects with a positive cost/benefit, and keeping a priority list of projects for future technologies that will increase the organization's chances of success. Scope and strategic alignment will help stakeholder engagement especially for these projects. In the project evaluation, many different criteria such as strategic suitability, technical feasibility, capacity, project cost and risks are considered. The risks in

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the selection of these projects are quite high, as the selection of unsuitable projects in the wrong evaluation results will cause significant financial, temporal and human resource losses for the companies [1]. Decision-making can be considered as a complex process, since there are multiple stages in this process, different decision-making groups are involved, and there are conflicting goals for different purposes [3]. Various studies have been conducted on the way organizations make these decisions [3–6]. Due to the uncertainty and different criteria in the projects, Golabi [7] conducted a study related to the maximization of the total values of the projects by using the multi-featured utility theory with integer linear programming. Bard et al. [8] worked on a decision support system to evaluate projects. Stewart [9] introduced a decision support system for a nonlinear optimization in portfolio planning. Traditionally, net present value (NPV), internal rate of return (IRR), and payback period have been used extensively as investment valuation techniques. Iyigium [10] proposed a decision support system for project selection using the Delphi technique. Additionally, Turner and Cochrane [11] published a study of well-defined projects and methods. Chui and Chan [12] proposed a method that evaluates the conditions for the success or failure of an R&D project and uses the net present value. However, there has always been a need to add non-quantitative criteria to the studies in addition to the mathematical studies carried out. For this reason, the multi-criteria decision-making technique started to be used for project selection in the following years. Saaty [13] introduced Analytical Hierarchy Process (AHP) for a method of multi-criteria decision-making. Liberatore [14] created a spreadsheet for project evaluation based on AHP. Brenner [15] proposed a method using the systematic project selection process using AHP for Air Products.

Considering these studies, classification has been made for decision models in project selection; scoring, mathematical programming, economic model, decision analysis, artificial intelligence, and portfolio optimization [4]. However, since the R&D project selection process is a decision-making problem that requires considering many interrelated and contradictory criteria, the use of multi-criteria decision-making methods has taken its place in the literature in order not to overlook the situations that may cause errors, to manage uncertainties correctly, and to evaluate more than one alternative criterion [16].

In this study, an application is conducted to evaluate the ideas of the R&D projects that will be started in the R&D center of an automotive company and the project selection. This application uses the fuzzy TOPSIS method, which is one of the multi-criteria decision-making methods. The linguistic equivalents of the evaluation of the criteria used in the selection of the projects by the experts were shown with fuzzy triangular numbers and the project selection is utilized with the fuzzy TOPSIS method. The main reason for the use of fuzzy triangular numbers in practice is that these numbers are easier to respond to linguistic evaluations, the sensitivity of the numbers is higher, and they provide ease of operation in terms of real application compared to other fuzzy numbers.

2 Material and Methods

2.1 Fuzzy Approach

Classical sets are not always sufficient when it comes to linguistic variables in decision-making. Linguistic variables are very useful in situations where there is complexity and there are no clear results [17]. It is not entirely clear what these expressions will mean quantitatively. In this case, fuzzy logic comes into play and dealing with fuzzy numbers can meet the situation.

In classical sets, an object is either a member of a set or not. In fuzzy sets, on the other hand, there are different degrees of membership to the set. In this way, objects can provide membership to sets. In classical set concept, if an object is a member of a set, its membership degree is evaluated as 1, otherwise it is evaluated as 0. No value other than these two values can be considered. In fuzzy sets, it is possible to talk about different values between 1 and 0 values. In fuzzy sets, the membership degree is the name given to each value between 0 and 1. The changes given under each of these are called membership functions. Objects gathered under membership functions have different membership degrees according to their importance.

In this study, triangular membership function is used. In Fig. 1, the triangular membership function and the elements of the triangular fuzzy set are defined as $\tilde{A} = (a, b, c)$ function [18]. Accordingly, the membership function $\tilde{A}$ is determined as $\mu\tilde{A}: x \rightarrow [0,1]$.

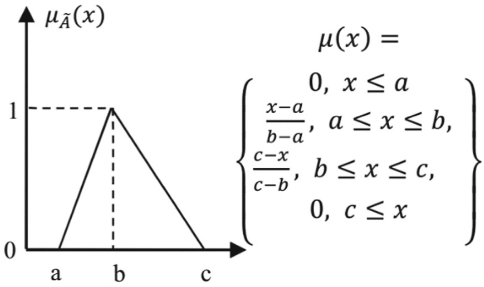

Fig. 1. Triangle Membership Function [19]

2.2 Fuzzy TOPSIS

TOPSIS is one of the most widely used multi-criteria decision-making techniques developed by Hwang and Yoon [20]. The method provides the evaluation of alternatives according to ideal solutions with the Euclidean distance approach. While looking at ideal solutions, it aims to choose the solution closest to the positive ideal solution and the farthest from the negative ideal solution. Fuzzy TOPSIS, on the other hand, is a method used in the evaluation of fuzzy environment developed by Chen [17]. The fuzzy TOPSIS method is useful for solving problems where there are uncertainty and more than one decision maker. In this method, as mentioned before, linguistic expressions are mostly used because there is uncertainty. Decision makers make their evaluations using linguistic expressions, and then these evaluation results are processed by converting them into trapezoidal or triangular fuzzy numbers. The fuzzy TOPSIS steps are as follows [17];

Step 1: The criteria and alternatives clusters are created by the decision makers. Linguistic expressions are used in the evaluation of alternative criteria and determination of weights. The five-point Likert-type linguistic scale used in this study is as shown in Table 1 [20].

Table 1. Fuzzy Evaluation Scores for Alternatives [21].

Linguistic Scale	Triangular Fuzzy Scale
Very unimportant	(0, 0, 0,25)
Unimportant	(0, 0.25, 0,5)
Moderately important	(0.25, 0.5, 0,75)
Important	(0.5, 0,75, 1)
Very important	(0.75, 1, 1)

Step 2: The evaluation results of the decision makers using linguistic expressions are converted into fuzzy numbers using Table 1. Then, using Eq. (1), alternative evaluations of the decision makers are made according to each criterion.

$$\widetilde{x_{ij}} = \frac{1}{K}[\tilde{x}_{ij}^{1}(+)\tilde{x}_{ij}^{2}(+)\ldots(+)\tilde{x}_{ij}^{K}] \tag{1}$$

Step 3: The alternative weights, and fuzzy degrees are obtained according to each criterion, and the fuzzy multi-criteria decision-making matrix is as in Eq. (2).

$$D = \begin{bmatrix} \widetilde{x_{11}} & \ldots & \widetilde{x_{1n}} \\ \ldots & \ldots & \widetilde{x_{2n}} \\ \widetilde{x_{m1}} & \ldots & \widetilde{x_{mn}} \end{bmatrix} \tag{2}$$

The linguistic expressions $\left(\widetilde{X_{ij}}\right)$ are expressed with triangular fuzzy numbers like $\left(\widetilde{X_{ij}}\right) = \left(a_{ij}, b_{ij}, c_{ij}\right)$.

Step 4: The normalized fuzzy matrix is expressed with $\tilde{R}$ using Eq. (3). Normalization process is performed using Eqs. (4)–(7). The aim here is to transform the numbers into triangular fuzzy numbers normalized between [0,1].

$$\tilde{R} = \left[\tilde{r}_{ij}\right]mxn \tag{3}$$

Decision criteria are divided into two as benefit and cost oriented. Here, it is assumed that B shows the benefit criteria and C shows the cost criteria;

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), j \in B; \tag{4}$$

$$\tilde{r}_{ij} = \left(\frac{a_j}{c_{ij}^*}, \frac{a_j}{b_{ij}^*}, \frac{a_j}{a_{ij}^*}\right), j \in C; \quad (5)$$

$$c_{ij}^* = \max_i c_{ij}, j \in B \quad (6)$$

$$a_j^- = \min_i a_{ij}, j \in C \quad (7)$$

Step 5: After the normalization process, a weighted normalized fuzzy decision matrix is created by using different weights for each criterion, if any, or by using equal weights for each criterion.

$$\tilde{V} = \left[\tilde{v}_{ij}\right] mxn, \ i = 1, 2, 3, \ldots, m, \ \ j = 1, 2, 3, \ldots, n \quad (8)$$

$$\tilde{v}_{ij} = \tilde{r}_{ij}(x)\tilde{w}_j \quad (9)$$

Step 6: Considering the weighted normalized fuzzy decision matrix, the elements $\left(\widetilde{v_{ij}}\right), \forall i, j$ normalized triangular positive fuzzy numbers are expressed in the range [0,1].

The fuzzy positive ideal solution $(FPIS, A^*)$ and the fuzzy negative ideal solution $(FPIS, A^-)$ are defined using Eqs. (10) and (11).

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*) \quad (10)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-) \quad (11)$$

$$\tilde{v}_j^* = (1, 1, 1) \text{ and } \tilde{v}_j^- = (0, 0, 0), j = 1, 2, 3, \ldots, n$$

Step 7: The distances of each alternative from A* and A$^-$ are calculated (d_i^* and d_i^-) using Eqs. (12) and (13).

$$d_i^* = \sum_{j=1}^{n} d(\tilde{V}_j, \tilde{V}_j^*), i = 1, 2, \ldots, m \quad (12)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{V}_j, \tilde{V}_j^*), i = 1, 2, \ldots, m \quad (13)$$

Step 8: The closeness coefficients of each alternative are calculated using Eq. (14) to determine the alternative ranking.

$$cc_i = \frac{d_i^-}{d_i^- + d_i^*}, \ i = 1, 2, \ldots, m \quad (14)$$

According to these calculated values, the one with the highest closeness degrees in the ranking can be considered as selected.

3 Case Study

This application was carried out for the selection of projects to be started in the R&D center of an automotive company established in Türkiye. The fuzzy TOPSIS method was used for problem solving. The use of linguistic expressions and the absence of clear values in the fuzzy TOPSIS method made it easier for the experts to evaluate the projects during the implementation. In this way, the selection was made by obtaining objective evaluations by the experts.

Project evaluation criteria used in practice are expressed by the set K, $K = \{K_1, K_2, K_3, K_4\}$. As the evaluation criteria of the projects; the impact of the project (K1), the cost of the project (K2), the feasibility of the project (K3) and the added value (K4) in terms of innovation, which is considered as the innovative aspect of the project, were taken into consideration. The set of alternative projects is denoted by P, $P = \{P_1, P_2, P_3, P_4, P_5, P_6\}$. In this application, 6 new project ideas were evaluated in total.

The evaluation of the relationship between alternative project ideas and the criteria was performed by 7 experts working in different fields in the R&D center for a long time, using the linguistic expressions in Table 1. Evaluations of experts in linguistic variables is given in Table 2.

Table 2. Evaluations of Experts in Linguistic Variables

Alternative/Criteria	K1	K2	K3	K4
P1	Very important	Unimportant	Moderately important	Very important
P2	Moderately important	Moderately important	Very important	Unimportant
P3	Moderately important	Moderately important	Moderately important	Unimportant
P4	Important	Moderately important	Moderately important	Important
P5	Moderately important	Unimportant	Moderately important	Important
P6	Moderately important	Moderately important	Moderately important	Important

Table 2 shows the degree of importance of the project alternatives according to the criteria. To apply this to fuzzy TOPSIS, the equivalent of the alternative-criteria evaluation with linguistic language for fuzzy numbers is given in Table 3.

As a result of the comparison of the criteria used in the project evaluation with each other, it was decided that their weights were equal and it was taken as 0.25 for each criterion. Equations (8) and (9) are calculated to obtain weighted fuzzy decision matrix. Then, the weighted fuzzy normalized decision matrix is obtained by the weighting process (see Tables 4–5).

Table 3. Equivalent of Table 2 for Fuzzy Numbers

Weight	0,25			0,25			0,25			0,25		
	K1			K2			K3			K4		
P1	0,75	1	1	0	0,25	0,5	0,25	0,5	0,75	0,75	1	1
P2	0,25	0,5	0,75	0,25	0,5	0,75	0,75	1	1	0	0,25	0,5
P3	0,25	0,5	0,75	0,25	0,5	0,75	0,25	0,5	0,75	0	0,25	0,5
P4	0,5	0,75	1	0,25	0,5	0,75	0,25	0,5	0,75	0,5	0,75	1
P5	0,25	0,5	0,75	0	0,25	0,5	0,25	0,5	0,75	0,5	0,75	1
P6	0,25	0,5	0,75	0,25	0,5	0,75	0,25	0,5	0,75	0,5	0,75	1

Table 4. Weighted Fuzzy Normalized Decision Matrix for K1-K2

	K1			K2		
P1	0.090951	0.156174	0.242536	0	0.058926	0.25
P2	0.030317	0.078087	0.181902	0.066815	0.117851	0.375
P3	0.030317	0.078087	0.181902	0.066815	0.117851	0.375
P4	0.060634	0.11713	0.242536	0.066815	0.117851	0.375
P5	0.030317	0.078087	0.181902	0	0.058926	0.25
P6	0.030317	0.078087	0.181902	0.066815	0.117851	0.375

Table 5. Weighted Fuzzy Normalized Decision Matrix for K3-K4

	K3			K4		
P1	0.032009	0.083333	0.032009	0.083333	0.032009	0.083333
P2	0.096028	0.166667	0.096028	0.166667	0.096028	0.166667
P3	0.032009	0.083333	0.032009	0.083333	0.032009	0.083333
P4	0.032009	0.083333	0.032009	0.083333	0.032009	0.083333
P5	0.032009	0.083333	0.032009	0.083333	0.032009	0.083333
P6	0.032009	0.083333	0.032009	0.083333	0.032009	0.083333

Equation (10)–(13) was used to measure the distances of the weighted fuzzy normalized decision matrix from the ideal negative and ideal positive solutions. As a result of calculating the relative closeness to the ideal solutions, the values were calculated by using Eq. (14) for the closeness coefficient values of the alternatives for the ranking. The closeness coefficients and rankings of the alternatives are given in Table 6.

As can be seen from Table 6, the P5 was found to be the first project to be initiated by the R&D department.

Table 6. Closeness Coefficient of Alternatives and Ranking

Alternative	c_i	Ranking
P1	0.582059	2
P2	0.456326	6
P3	0.459195	5
P4	0.504535	4
P5	0.620146	1
P6	0.551704	3

4 Conclusion

In this study, Fuzzy TOPSIS method was conducted to select the best R&D projects in the R&D center of an automotive company. The feasibility of the project, the cost of the project, the impact of the project and the contribution of the project to the innovation criteria are evaluated by experts for 6 projects that were considered as alternatives in practice. Since these evaluation results are expressed linguistically, their equivalents with fuzzy numbers are taken into account in the application of the method. With the ranking obtained as a result of the application, the P5 was found to be the first project to be initiated by the R&D department.

R&D project selection evaluation can be performed with other decision-making methods such as fuzzy TOPSIS method in future studies. Project selections can be utilized by using 7-likert-type different scales instead of the 5-point likert scale.

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