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Conference Article

Evaluating R&D Projects Using Two Phases Fuzzy AHP and Fuzzy TOPSIS Methods

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Abstract

Technology provides important contributions to economic growth by increasing productivity in production. One of the most important indicators of technological innovation is research and development (R&D) activities. R&D studies have become necessary for companies to have a competitive advantage and to continue their operations more profitably. The decisions taken by companies and the investments they make have become more important than ever for their institutional future. In this sense, investments and projects in the R&D have become a decisive factor in the future of companies, moving companies away from traditional financial approaches that only aim at cost or profit. Decisions to be made in this issue have a more complex structure than ever, and their effectiveness has become critical for corporations. In this study, a two-stage model is proposed for the decision of an R&D project selection decision of an energy company. In the model, the weights of the criteria are determined using the Fuzzy AHP (Analytical Hierarchy Process) method and the most appropriate project is determined by the Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solutions) method.

Keywords: R&D projects; project selection; fuzzy multi-criteria decision making methods.

1. Introduction

Technological innovations have reached the entire world to a new dimension called globalization by providing significant contributions to the economies of the countries. Especially with the rapid development of new technologies in recent years, the production and consumption of products and services have become easier and globalized all over the world. Research and development (R&D) activities are the leading activities of these technological innovations which are direct effects of increasing productivity in production. In the economic environment pioneered by science and technology, R&D has many advantages such as competitive advantage, more innovative approach to production, lower cost and higher quality (Polat, 2016). Therefore, in the new global world, R&D has become a necessary condition for businesses to continue their activities by continuing their profits. Reduce a business's production costs as a result of a new product or process development leads to a significant increase in their market share. Therefore, there is a great need for R&D activities for businesses to protect or increase profit sharing, which is the main objective of them and to use their existing resources effectively.

In the management activity, all of the choices in the subject such as which goals are to be taken the forefront, which opportunities are to be created, which resources are to be allocated within the framework of the principles, and who will execute the decisions taken are a decision (Onursal, 2009). The aim of the decision-making is to choose the most effective alternatives available for a particular purpose. In the simplest terms, a decision problem is a selection process between alternatives according to a purpose or constraint. However, in some cases, decision problems may not be expressed mathematically or may need to be expressed linguistically. Fuzzy multi-criteria decision-making methods can be used in problems that need to be expressed in linguistic variables (Toklu, 2017).

Investments and projects in the R&D field have become more important than ever for the companies in order to be able to create and protect their corporate future. Hence, businesses have to decide the most appropriate project according to their needs and expectations between the many R&D investments or projects that can be done in the future. The accuracy of the decision is extremely important because of the benefits and advantages of R&D projects are understandable in the long term (Bilici, 2002). Thus, in this study, the criteria are selected from the criteria used by organizations that support R&D projects such as TUBITAK, the EU Framework Programme for Research and Innovation (HORIZON 2020) and KOSGEB and implemented in an energy company.

The aim of this study is to develop a two-stage systematic decision-making process for the evaluation of the projects considered to be implemented in the R&D department of a company operating in the energy sector. The reason for the implementation of this study to the energy sector is that the data of the projects can be obtained from a company operating in the

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relevant energy sector. It is also possible to apply the model to other sectors. In the Method section, it is mentioned why these methods are preferred. In the first stage of the process, it is aimed to examine the competence of the projects according to their R&D content, and to examine the competence of the company for the projects that passed to the second stage.

In this context, it is aimed to rank R&D projects according to their importance, and it is planned to select the projects with the highest application potential in the firm. The proposed model consists of two stages. In the first stage, weights of criteria are determined using the Fuzzy AHP method. The importance degrees of the projects are determined by Fuzzy TOPSIS method in the second stage that the weights of the alternative projects are evaluated and ranked.

2. Method

2.1. Fuzzy Analytical Hierarchy Process

The fuzzy analytic hierarchy process (AHP) is an appropriate method to decide in case of ambiguity that the inter-criterion relations can only be expressed linguistically (Erdem, 2016). In this study, the Fuzzy AHP method proposed by Buckley (1985) is used to determine the weights of the criteria. This method is based on a fuzzy pairwise comparison matrix of all the criteria considered in a hierarchical structure.

2.2. Fuzzy TOPSIS

The Fuzzy TOPSIS method helps to decide on flexible fuzzy situations, which consist of values of both linguistic and numerically expressed decision criteria (Değermenci ve Ayvaz, 2016). It's frequently found in the literature that Fuzzy TOPSIS is suitable for use in solving problems that need to be decided by more than one person. One of the important reasons for choosing the fuzzy method is that it allows the decision makers to express criteria by using linguistic variables in situations where the criteria cannot be determined numerically. In this study, Fuzzy TOPSIS method developed by Chen (2000) is used.

3. Implementation

Within the scope of the study, the criteria used in the evaluation of the projects are decided first. Importance degrees between the main criteria and sub-criteria are determined by three experts using pairwise comparisons obtained by three questionnaires. A two-stage model is used in this study. The flow chart of the model used in the study is shown in Figure 1.

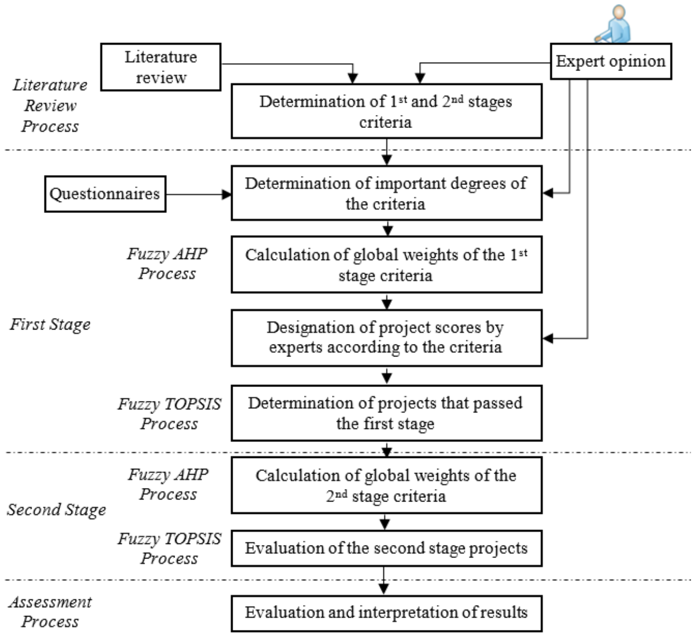

Figure 1. The flow chart of the model

At the first stage of the model, it is decided which projects will be passed to the second stage. In the second stage, only the projects passed the first stage are taken into consideration and the most appropriate one is selected from these projects. In both stages, the importance degrees of the projects are determined according to the scores they have received at the end of an integrated Fuzzy AHP - Fuzzy TOPSIS process. The weights of the criteria to be used in the Fuzzy TOPSIS method are determined by the Fuzzy AHP method. The main and sub-criteria used in both stages of the study are shown in Table 1 and Table 2.

Table 1. Main and Sub-Criteria of Stage 1.

Main Criteria
**** Innovative Aspect*** **** R&D Content*** **** Technology Level*** **** Economic Benefits of the Project Outputs***
Sub-Criteria
**** Innovative Aspect (C1)*** - Development of new models of an existing product in the company **(C11)** - Developing a new product for the company **(C12)** - Developing a new product platform for the company **(C13)** - Developing a new product for the country **(C14)** - Developing a new product for the world **(C15)**
**** R&D Content (C2)*** - Potential to conclude with fundamental intellectual and industrial property rights to protect **(C21)** - Applying a known method, technique or technology to a new field, sector, product or process **(C22)** - Implementation of a method, technique or process other than known **(C23)** - Working in different technology areas **(C24)** - The potential of the project launches new R&D projects **(C25)** - Possible investments in establishing the production /laboratory / testing infrastructure of the project **(C26)**
**** Technology Level (C3)*** - Implementation and development of new techniques to obtain cost reduction results **(C31)** - Development and application of new techniques to obtain standard/quality improvement results **(C32)**

- Development of a new method related to production **(C33)**
- Development of a new technology related to production **(C34)**

**** Economic Benefits of the Project Outputs (C4)***
- The outputs of the project increase the competitiveness on the national scale **(C41)**
- The outputs of the project increase the competitiveness on the international scale **(C42)**
- The outputs of the project must have the qualification as a substitute for imported product **(C43)**
- Project output has the possibility of export **(C44)**

Table 2. Main and Sub-Criteria of Stage 2.

Main Criteria
**** Organization Substructure***
**** Planning***
**** Budget***
Sub-Criteria
**** Organization Substructure (C1)***
- The expertise and competencies of the staff are compatible with the project **(C11)**
- Laboratory possibilities **(C12)**
- Test environment possibilities **(C13)**
- Tool-and-equipment possibilities **(C14)**
- Software tools possibilities **(C15)**
**** Planning (C2)***
- Project plan is realistic and practicable **(C21)**
- Work packages are suitable for workflow and timeline **(C22)**
- The connections between business packages are defined **(C23)**
- The duration of the project is suitable for the scope of the project **(C24)**
**** Budget (C3)***
- Project expenditure items are suitable for the work to be done in quantity and quality **(C31)**
- Additional investment requirement of the project **(C32)**
- Academic consultancy requirement of the project **(C33)**

The data from the three questionnaires are used as input to implement the Fuzzy AHP method and a single pairwise comparison matrix for each table is obtained by taking the average of the answers given by the decision makers. In the Fuzzy AHP implementation, pairwise comparisons are made for all the main and sub-criteria and the global weight values are determined for all of the first and the second stage criteria with the help of the obtained matrices. Table 3 shows the results of the global weight calculated using the Fuzzy AHP, which will be used as input in the Fuzzy TOPSIS implementation at the second stage.

Table 3. Calculated Global Weight Values for All Criteria (Stage 1).

Main Criteria	**Sub-Criteria**	**Importance Degrees (W*)**		
		Sub-Criteria	**Main Criteria**	**Global Weight**
Innovative Aspect C1	**C11**	0.050	0.169	0.008
	C12	0.086		0.015
	C13	0.150		0.025
	C14	0.261		0.044
	C15	0.453		0.077
R&D Content C2	**C21**	0.398	0.219	0.087
	C22	0.081		0.018
	C23	0.214		0.047
	C24	0.115		0.025
	C25	0.152		0.033
	C26	0.040		0.009
Technology Level C3	**C31**	0.485	0.093	0.045
	C32	0.185		0.017
	C33	0.170		0.016
	C34	0.160		0.015
Economic Benefits of the Project Outputs C4	**C41**	0.276	0.519	0.143
	C42	0.500		0.259
	C43	0.126		0.065
	C44	0.099		0.051

In the Fuzzy TOPSIS implementation, three decision-makers who evaluated the importance degrees of selected criteria using linguistic variables for 15 alternative R&D projects assign scores. Criteria weights that are used in ranking the projects are taken from Table 3. Fuzzy TOPSIS steps are applied for 15 alternative projects and the closeness from the ideal solution for each alternative is determined. The rank of the alternative projects is as shown in Table 4.

Table 4. Evaluation Results of Stage 1.

Project	**D^+**	**D^-**	**SC_i**	**Project Scores**	**Project Scores Passed the Stage 1**
1	14.4	5.2	0.266	0.075	**0.075**
2	15.0	5.1	0.254	0.071	**0.071**
3	16.4	4.8	0.225	0.063	-
4	16.2	5.5	0.253	0.071	**0.071**
5	15.5	6.9	0.306	0.086	**0.086**
6	14.9	5.0	0.252	0.071	**0.071**
7	13.5	7.0	0.341	0.096	**0.096**
8	16.8	4.4	0.208	0.059	**-**
9	16.1	3.7	0.187	0.053	**-**
10	15.6	3.9	0.201	0.057	**-**
11	15.8	3.6	0.184	0.052	**-**
12	14.9	4.6	0.236	0.067	**0.067**
13	16.2	3.8	0.191	0.054	**-**
14	17.0	4.6	0.214	0.060	**-**
15	15.0	4.5	0.231	0.065	**-**

Table 4 shows that the projects are evaluated based on the innovative aspect of the project, the R&D content, the technology level and the economic benefits of the project outputs and the projects above the average value (0.067) are selected as projects that will pass to the second stage. This value is chosen as the common idea of the experts. In the second stage of the implementation, the projects numbered 1, 2, 4, 5, 6, 7 and 12 successfully passed from the first stage are evaluated. In the second stage, the criteria weights are calculated with Fuzzy AHP, and the rank of the alternatives is determined by the Fuzzy TOPSIS method. Table 5 shows the results of the global weight calculated using the Fuzzy AHP, which will be used as input in the Fuzzy TOPSIS implementation at the second stage.

Table 5. Calculated Global Weight Values for All Criteria (Stage 2).

Main Criteria	**Sub-Criteria**	**Importance Degrees (W)**		
		Main Criteria	**Sub-Criteria**	**Global Weight**
Organization Substructure C1	**C11**	0.495	0.532	0.263
	C12	0.124		0.066
	C13	0.124		0.066
	C14	0.154		0.082

	C15	0.102		0.054
Planning C2	**C21**	0.250	0.313	0.078
	C22	0.250		0.078
	C23	0.250		0.078
	C24	0.250		0.078
Budget C3	**C31**	0.349	0.155	0.054
	C32	0.145		0.022
	C33	0.507		0.078

In the Fuzzy TOPSIS implementation, scores of 7 alternative R&D projects passed from the first stage are assigned by three decision makers. Criteria weights that are used in ranking the projects are taken from Table 5. The choice of the best one among the 7 alternative projects is determined by the Fuzzy TOPSIS method and the evaluation results are shown in Table 6.

Table 6. Evaluation Results of Stage 2.

Project	D^+	D^-	SC_i	Project Scores	Priority Projects
1	13.9	21.9	0.39	0.065	-
2	14.3	21.5	0.40	0.067	-
4	13.8	22.6	0.38	0.063	-
5	18.2	25.3	0.42	0.070	**0.070**
6	14.1	22.9	0.38	0.064	-
7	14.7	20.8	0.42	0.069	**0.069**
12	14.8	21.4	0.41	0.068	**0.068**

4. Conclusion

In this study, a two-stage decision-making model is established based on the selection of the best value-added projects which are both compatible with the strategic goals and organizational expectations of the company and have the potential to provide maximum profit for the R&D projects of an energy company. In the first stage of the developed model, relations between R&D projects are analyzed using integrated Fuzzy AHP and Fuzzy TOPSIS methods. 15 projects are evaluated and 7 projects passed the second stage with a score above the threshold value. In the second stage, 7 projects that passed the first stage are ranked using Fuzzy AHP and Fuzzy TOPSIS methods, and the best 3 applicable projects are determined.

When looking at the global weights of the first stage criteria (Table 3), it is seen that “economic benefits of the project outputs” is the most important criterion according to Fuzzy AHP results. Generally, the criteria are sorted from greater to smaller according to importance ratings as Economic Benefits of the Project Outputs, R&D Content, Innovative Aspect and Technology Level, respectively.

When looking at the global weights of the second stage criteria (Table 5), it is seen that “organization substructure” is the most important criterion and the ranking among the criterion weights is Organization Substructure, Planning and Budget.

In future works, it is planned that the evaluation of important projects in different fields will be realized by using different alternative techniques such as MOORA, WASPAS, VIKOR etc..

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