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Evaluation of R&D and innovation projects using analytical network process

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Abstract
In a fierce competitive environment, companies have turned to R&D and innovation projects in order to survive with higher profits. However, under rapidly changing economic conditions, it is necessary to make the right decisions about the selection and investment of the most suitable R&D and innovation projects in a way to maximize / minimize the benefit / cost criteria with limited financial resources. Because choosing the right project is critical to the success of the organization. In addition, the mistake to be made in the selection will cause the resources to be spent on unsuitable projects, and therefore, insufficient resources for projects that will provide more benefits for the organization. Therefore, using multi-criteria decision-making methods for evaluating R&D and innovation projects, which contain many uncertainties and criteria, and selecting the most suitable project, will ensure that the right decisions are made. Therefore, using multi-criteria decision-making methods for the evaluation and selection of R&D and innovation projects, which contain many uncertainties and criteria, will ensure that the right decisions are made. In this study, first a comprehensive literature review is presented on the selection of R&D and innovation projects. Then Analytical Network Process (ANP) method, which is one of the multi-criteria decision-making methods, which takes into account the interaction between criteria in the evaluation phase, is used to evaluate the R&D and innovation projects in a company's project portfolio and to solve the problem of choosing the most suitable project. As a result of the evaluations made according to the network model created by the Super Decisions 2.10 program, product differentiation, benefit to customer, impact on market growth and technical challenge are determined as the most important criteria and the best R&D and innovation project is chosen.

Keywords: R&D, innovation projects, MCDM, ANP.

1. Introduction

In a fierce competitive environment, companies have turned to R&D and innovation projects in order to survive with higher profits [1]. However, long delivery times, variability in the market and business environment (customer expectations, company strategies, environmental factors, technological requirements etc.) and the change in the available information as the project progressed made R&D and innovation projects extra complex [2, 3]. Under rapidly changing economic conditions, companies have to make regular decisions about which R&D and innovation projects to invest in. Such decisions, which are evaluated under the title of R&D and innovation project portfolio management, have a direct effect on the profitability, sustainability and growth of companies [4]. Jonas [5] defined the portfolio as a group of projects competing for scarce resources run under a sponsorship or management. Project portfolio management in its most general form is all of the management activities related to the screening, selection and prioritization of project proposals, allocation of resources to projects according to priority [6].

R&D and innovation project portfolio selection, which aims to allocate limited resources to projects by considering the balance between risk benefit and compliance with corporate strategy, has many benefits such as revealing the weaknesses and strengths of projects, encouraging systematic analysis, allowing even non-technical managers to make evaluations, and making future opportunities and gaps visible [7]. With these advantages, the project selection contains many difficulties. Therefore, although a lot of study has been done so far, there are always future study opportunities [8].

The first option that comes to mind about how to carry out the selection process is to calculate the expected benefit and the investment to be made for each project and then to make a choice according to the Return on Investment ratio (ROI). Although financial projections, another option, are frequently used by managers, there may be uncertainties regarding financial information especially in R&D and innovation projects in the early period. Cooper et al [9] revealed that financial

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information is the least trusted parameter. Another common approach is to choose according to intuition. The intuitive decision can be effective in situations where many examples are encountered. However, using intuition for rare situations such as R&D and innovation projects will not be very effective [2]. In addition, besides the classical criteria such as profit or customer satisfaction, qualitative or quantitative criteria such as social behavior, differences in evaluation, stakeholder perception, business policies should be evaluated for selection. This makes it very difficult to make a good selection manually or intuitively. The mentioned difficulties and advances in computer technology have led researchers to computer-aided analytical approaches (multi-criteria decision making, mathematical modeling, etc.) [1]. These approaches are effective tools for optimizing the long-term growth and profitability of businesses and offers managers the opportunity to systematically manage R&D and innovation projects [8].

In this study, it is aimed to evaluate the R&D and innovation project ideas in a company's project portfolio and to select the most suitable one. The ongoing parts of the study are organized as follows: In the second part, the literature on R&D and innovation project selection is included, in the third part, the ANP method used for selection is explained, and in the fourth part, the projects are evaluated and the best project is selected, and the results and evaluations are given in the last part.

2. Literature review

The R&D and innovation project management process, which can be evaluated under two main headings as collecting and selecting project proposals, should be meticulously managed from end to end. In collecting project proposals, companies have turned to an open innovation strategy in order to benefit from internal and external resources in an easier and less costly way. Development in information technologies, especially in the field of mobile communication, has made it very easy to collect new ideas. After collecting the collected suggestions in the pool called the project portfolio, the main problem is the selection of the most suitable projects in a way that maximizes/minimizes the benefit/cost criteria with limited financial resources. Choosing the right project is critical to the success of the organization, and the mistakes to be made in the selection will cause the resources to be spent on unsuitable projects, and therefore, the lack of resources for the projects that will provide more benefits for the organization [10]. The critical importance of R&D and innovation projects in the maintenance of companies, the dynamism and uncertainty in the structure of the process have led researchers from both academic and practical life to work intensively on this issue. In the last 10 years, many decision models such as economic models, mathematical programming, meta-heuristic techniques and hybrid techniques have been developed for the selection of the most suitable R&D project [4].

Liberatore and Titus [11] stated that because of the wide variety of project types, resources and criteria, mathematical modeling approaches such as integer and linear programming are not widely used in R&D and innovation projects. Also, Coldrick et al. [12] stated that mathematical modeling is not practical for R&D and innovation project selection due to reasons such as the complexity of R&D and innovation project selection in many aspects, the existence of interaction between projects, and the change in the project and the success factor over time. Although economic models evaluate R&D and innovation projects according to more concrete monetary components, they cannot include subjective expert opinions in the selection process. The same is true for mathematical models. Therefore, especially multi-criteria decision-making techniques seem more suitable for R&D and innovation project selection [2, 11]. In this context, regarding the selection of the most suitable R&D project in the last 10 years many multi-criteria decision making techniques such as Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Data Envelopment Analysis (DEA), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) have been proposed [4]. In this section, current literature is reviewed in the context of multi-criteria models developed for R&D and innovation project selection and presented below.

Souza et al. [1] examined the criteria to be used in portfolio selection for R&D projects in an uncertain environment, according to their impact and importance. They proposed a new hybrid approach for criteria selection, which consists of the integration of fuzzy DEMATEL and fuzzy AHP. In addition, the authors presented a case study of an R&D company operating in Brazil. In most of the previous studies, it was assumed that the projects were carried out without interruption. However, projects can be carried out in pieces due to reasons

such as reducing the waste of resources in real life, smoothing the use of resources, and being able to make flexible and effective scheduling. RezaHoseini et al. [13] selected under budget and resource constraints in his study, which considered this situation. They set the sustainable balanced scorecard as a time-dependent criterion. The authors also included the advantages and disadvantages of running projects in pieces: Partial execution reduces waste in resource use, allowing the project selection process to become more flexible and to select more projects. On the other hand, problems such as fluctuations in exchange rates, changing interest rates, inability to complete the project due to future uncertainty or excess cost are also disadvantages. Wannakul et al. [14] conducted a study on the selection of proposed R&D projects in order to receive Thai government support. In the study, three main factors (entrepreneur, researcher and project detail) and nine sub-factors were used as criteria. AHP was used for the solution. Gonçalves [15] reviewed 61 studies on the selection of R&D projects between 1970-2018 in his/her master's thesis. In the study, they tried to reveal which criteria were more effective in selection. They examined 27 sub-criteria under 8 main criteria. In the study, each criterion and sub-criteria were evaluated using AHP technique with two experts, one in energy and the other in technology. Mitchell et al. [2] used the scoring technique, one of the multifactorial techniques, where the selection process is conducted with less data. In this study, the authors discussed in detail how to design the scoring tool under subheadings. These sub-headings are: Factor selection, scoring in a logical and objective manner, the way to be followed in the inclusion of uncertainties in the process, selection of factors, establishing scoring as logically and objectively as possible, including uncertainties in the process and ensuring interdependence, trade-off and synergy balance between projects. Karasakal and Aker [16] used the data envelopment method to evaluate R&D projects. In this context, two threshold estimation models and five assignment models have been developed. The weights of the criteria were obtained by interval analytic hierarchy process. The hybrid approach developed has been compared with UTADIS, one of the leading sequencing methods. For comparison, 60 projects were used who want to benefit from a grant program of the government in Turkey.

The effectiveness of R&D and innovation time depends on the success of teamwork. Often differences in perceptions of team members hinder consensus and coordination efforts. That is why [4] developed a hybrid model, taking into account the stakeholders from different departments with various opinions. The authors used the DEMATEL approach to transform the cause and effect relationships representing the criteria into a visual network structure. CFPR-ANP (consistent fuzzy preference relations based analytic network process) was used to determine the priority weights of the criteria in the study. This technique is a specialized version of ANP to eliminate the inconsistency problem. In addition, the COPRAS-G (combined complex proportional assessment with fuzzy gray relations) method has been used to resolve the conflict arising from the difference of stakeholders' ideas and information regarding the selection of the most appropriate R&D and innovation project. This new hybrid method has been applied in the selection of R&D projects of a company that produces computer hardware. In practice, five candidate projects were evaluated according to thirteen sub-criteria under four main criteria. In addition, the authors classified the studies in literature according to the criteria and solution techniques in their studies and presented them in tables. Bhattacharyya [3] mentioned the selection process of a company operating in India among five candidate projects according to ten criteria. The authors stated that weighting with exact numbers would not be very realistic in the selection of R&D projects where there are uncertainties, and therefore a gray theory-based approach was adopted due to the uncertain environment in which the problem is located. Ratings and weights are expressed in linguistic terms with gray numbers.

Most of the studies in the literature focus only on resources, outputs or technical dependencies, neglecting the dependency between projects [8]. The existence of interdependence between projects means that the parameter related to one project changes according to another selected project. Therefore, as Markowitz [17] put it in the portfolio theorem, the total benefit obtained from the portfolio is not equal to the sum of each project separately [3]. Abbassi et al. [8] 0-1 non-linear model has been developed to balance portfolio values (return) and risk when research projects are interdependent (interacting). In addition, in related study, the cross-entropy algorithm developed by Rubinstein [18] for large-scale samples and applied for the first time [19] for combinatorial optimization problems was proposed. The authors evaluated a total of 34 criteria in two groups, internal and external (by organization). A Delphi-based survey was conducted on twenty experts and managers with technical backgrounds to reveal their relative importance. In the study conducted by Huang

and Chu [20] in which the interaction between projects was taken into account, the fuzzy ANP model was proposed for the selection of candidate projects from the private sector who wanted to benefit from the support program for the R&D projects managed by the government in Taiwan. The authors determined 30 criteria under four main criteria by scanning the literature and interviewing eight experts. In this study, it was stated that fuzzy AHP would be insufficient in case of interaction between criteria, whereas fuzzy ANP is the most appropriate method.

They also made a comparative assessment of R&D project selection models and techniques. de Gracia et al. [21] used AHP in the selection of ideas collected with an open innovation strategy in the energy sector. Criteria were determined according to PMI methodology. It has been evaluated according to 8 criteria under two main groups: technical and organizational. Pererva et al. [22], in their study on supermarkets, developed a methodology on the selection of innovative projects according to the integral index created according to economic efficiency (Net present value, cost benefit rate, internal rate of return, equivalent annual annuity, modified internal rate of return). Scoring was made according to the three-sigma rule and a selection was made among five alternative projects**.**

3. Analytical network process

Multi-criteria decision making (MCDM) is the process of evaluating a finite number of options by using a large number of criteria that are usually weighted for the purpose of selecting, ranking, classifying, prioritizing or screening, that do not use the same unit of measure, and some of them even take qualitative values [23, 24]. MCDM methods, on the other hand, help to determine the most suitable option by considering many criteria in decision-making processes [25, 26]. MCDM methods are analytical methods that provide the opportunity to evaluate many measurable and unmeasurable strategic criteria together and at the same time apply to the judgment of more than one person in the decision-making process [27, 28]. The problems to be solved may not always be expressed in a hierarchical structure. The criteria and alternatives involved in such problems may interact with each other. In this case, analysis of a more complex process is required to find the weights (relative importance vectors) of the components [23]. In this case, the ANP method, which takes into account the relationships between the criteria, which is an effective factor in the decision-making process, comes into play. The ANP method is a generalized form of AHP developed by Thomas L. Saaty. ANP is also a good analyzer when numerical factors cannot be expressed and can be applied to more complex decision-making problems compared to AHP [27, 29]. In the ANP method, the problem is modeled using the network structure, different from AHP (Figure 1). In this method, dependencies between criteria are taken into account. [30, 31].
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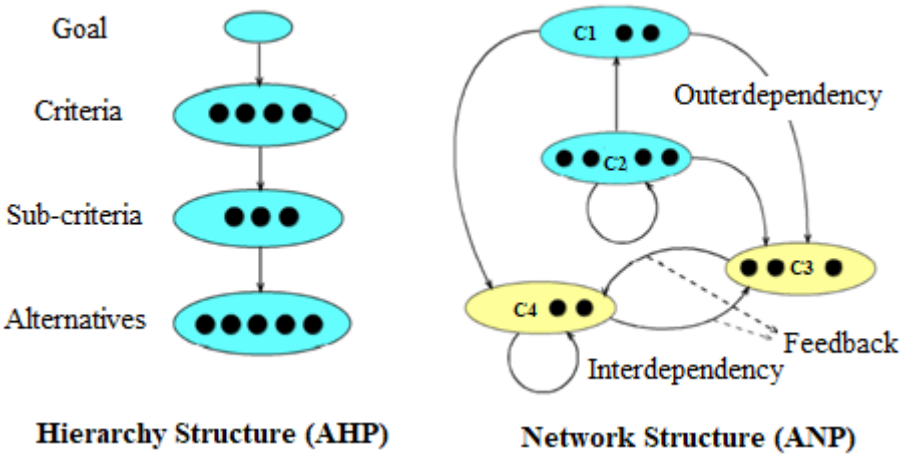


Figure 1. Hierarchy and network structure [31].

In the ANP method, as in the AHP approach, the criteria should be compared in pairs in order to determine the effects of the criteria on the model [32, 33]. The 1-9 scale developed by Saaty [34] is used in these paired comparisons.

Table 1. Importance values of pairwise comparison and their definitions [34]

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one over another
5	Strong importance	Experience and judgment strongly favor one over another
7	Very strong	Activity is strongly favored and its dominance is demonstrated in
9	Absolute importance	Importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate values	Used to represent compromise between the priorities listed above

3. Application

In this study, it is aimed to evaluate the R&D and Innovation projects in the project portfolio of a company with an R&D center and to choose the best among them. For this purpose, ANP method, which takes into account the interaction between criteria, has been used and the flow chart of this method is presented in Figure 2.

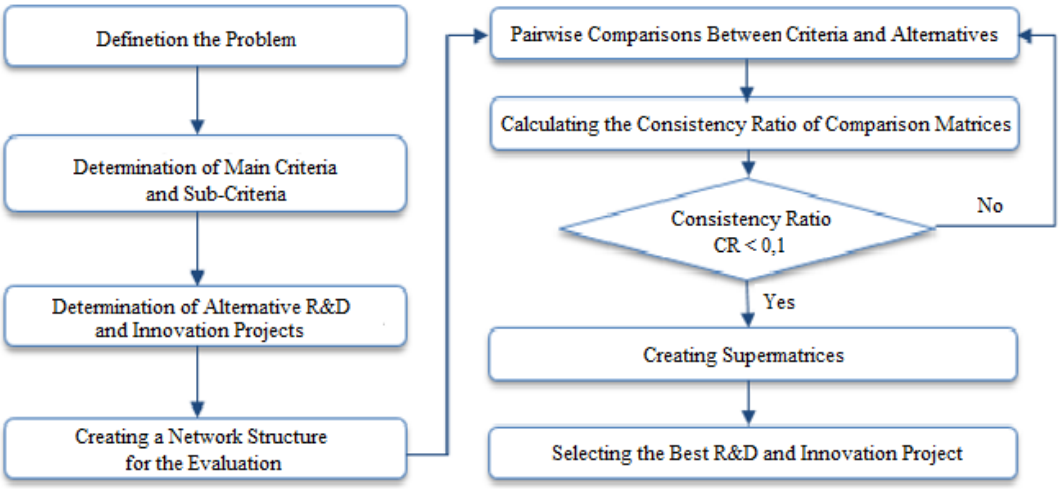


Figure 2. Flow chart for evaluation of R&D and innovation projects.

According to the flow chart created in Figure 2, the main and sub-criteria required for the evaluation of R&D and Innovation projects were determined by a literature review and a team consisting of the company's R&D Center Manager, innovation specialist and marketing department expert and shown in Table 2.

Table 2. R&D and innovation projects evaluation criteria

Main Criteria	Sub-Criteria
Company Benefit Criteria	Impact on Competitiveness
	Impact on Market Growth
	Contribution to Brand Image
Feasibility Criteria	Technical Challenge
	Required Technical Capacity
	Finance Requirement
Opportunity Criteria	Potential to Lead to Different Technologies
	Product differentiation
	Benefit to Customer
	Industry / Market readiness

After determining the R&D and innovation projects evaluation criteria, the interactions between the criteria were analyzed by a three-person expert and the interactive criteria were determined and given in Table 3.

Tablo 3. Criteria Interactions

Affected criterion	**Affecting criterion**
Impact on Competitiveness	Product differentiation
	Benefit to Customer
	Industry / Market readiness
	Potential to Lead to Different Technologies
Impact on Market Growth	Product differentiation
	Benefit to Customer
Contribution to Brand Image	Potential to Lead to Different Technologies
	Product differentiation
	Benefit to Customer
Product differentiation	Technical Challenge
	Required Technical Capacity
	Finance Requirement
Benefit to Customer	Product differentiation
	Potential to Lead to Different Technologies

Later, 5 projects (*P1, P2, P3, P4, P5*) in the company's project portfolio were determined. Afterwards, the connections between the specified criteria, internal and external dependencies and feedbacks were made with the help of Super Decision 2.10 software and the network structure in Figure 3 was created.

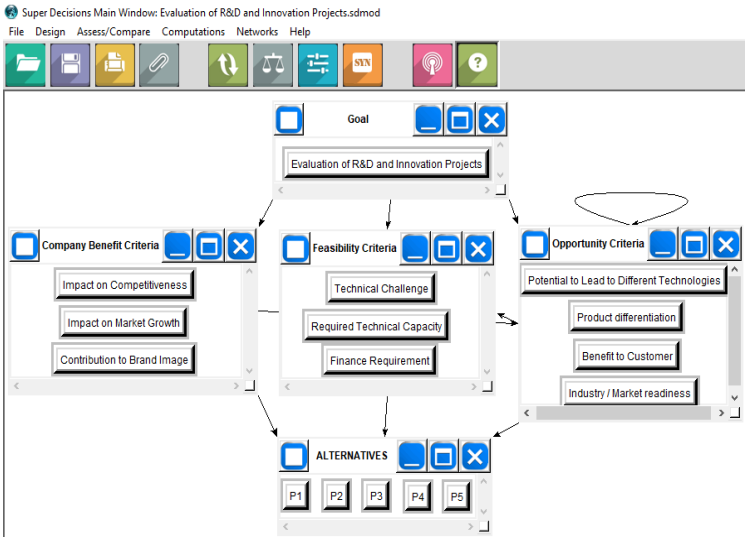
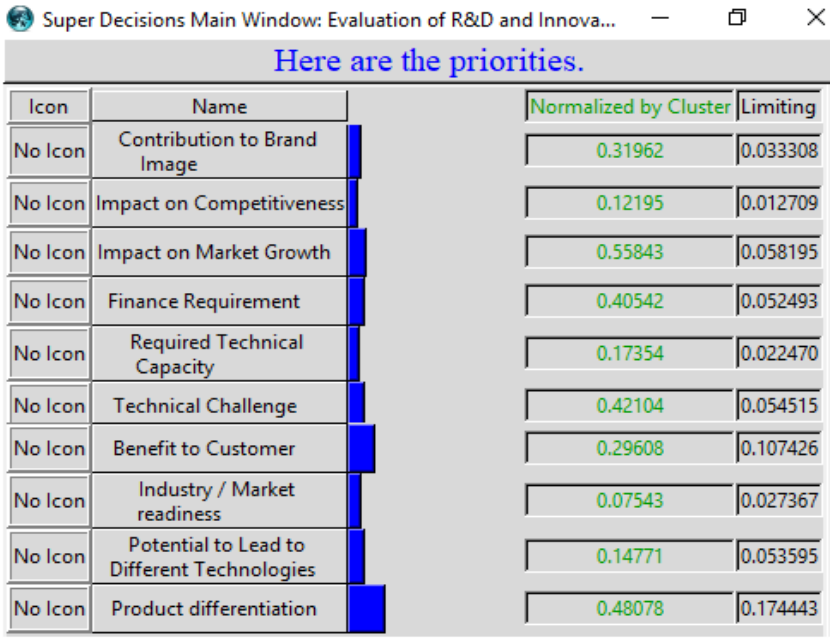


Figure 3. R&D and innovation projects assessment network structure

After the network structure was created, the necessary paired comparisons were made with the help of the scale specified in Table 1. These binary comparison evaluations were entered into the Super Decisions 2.10 program. Then, the priority values of the criteria in the model, which are in Table 4, and the unweighted supermatrix, the weighted supermatrix and the limit matrix, respectively, were obtained.

Table 4. Priorities of criteria for evaluation of R&D and innovation projects



When the priority values of the criteria in Table 4 are examined, it is seen that the most important criterion in evaluating R&D and innovation projects is the "*Product differentiation*" criterion with a priority value of 0.174. Other important criteria are listed as follows: "*Benefit to customer*" (0.107), "*Impact on market growth*" (0.058) and "*Technical challenge*" (0.054). Based on the calculated criterion weights, priority values and rankings for alternative R&D and innovation projects are included in Table 5.

Table 5. R&D and innovation projects priority values and ranking of preferences

Graphic	Alternatives	Total	Normal	Ideal	Ranking
	P1	0.1215	0.3011	1.0000	1
	P2	0.0715	0.1772	0.5886	4
	P3	0.0395	0.0978	0.3248	5
	P4	0.0804	0.1993	0.6619	3
	P5	0.0906	0.2246	0.7459	2

As seen in Table 5, the "*P1*" project ranks first among alternative R&D and innovation projects with a priority value of 30.11%. Among other projects, "*P5*" is the second with 22.46% priority value and "P3" is the last with 9.78% priority value. Considering the priority values, it would be appropriate to select the "*P1*" project as the best project among alternative R&D and innovation projects according to the criteria included in the model.

4. Conclusion

Today, companies' struggle to survive has intensified due to changing customer expectations and increasing competition conditions. Under these difficult conditions, it has become compulsory for companies to carry out R&D studies and transform these studies into innovation in order to extend their life. Companies that are aware of this necessity collect and evaluate ideas that will turn into innovation with both closed and open innovation methods, and include the best ones in their project portfolio. However, the necessity to consider many criteria in the evaluation of these collected ideas makes the evaluation process difficult. This situation brings multi-criteria decision-making methods to the foreground for the solution of the problem.

In this study, a multi-criteria decision-making application has been made in order to evaluate the R&D and innovation projects and to select the best project. ANP was chosen as the method because it takes into account the internal and external interactions between the evaluation criteria. In the study, the criteria that are

effective in the selection of R&D and innovation projects were determined and the necessary evaluations were made after the network structure was created in the Super Decision 2.10 program. At the end of the study, the project named "*P1*" was chosen as the most appropriate R&D and innovation project. When we look at the features of the selected project, it is seen that it has the feature of product differentiation, its contribution to the benefit to customer and market growth is higher than other projects and the technical difficulty in realization is less than other projects. Due to these features, it is predicted that the relevant project will be more beneficial both for the company and for customer expectations. The methods and criteria used in the model developed in this study will guide both companies and researchers in the evaluation of R&D and innovation project ideas, as well as other project ideas.

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References

[1] Souza, D. G., Silva, C. E., & Soma, N. Y. (2020). Selecting projects on the Brazilian R&D energy sector: a fuzzy-based approach for criteria selection. *IEEE Access*, 8, 50209-50226.

[2] Mitchell, R., Phaal, R., & Athanassopoulou, N. (2014, July). Scoring methods for prioritizing and selecting innovation projects. In *Proceedings of PICMET'14 Conference: Portland International Center for Management of Engineering and Technology; Infrastructure and Service Integration* (907-920). IEEE.

[3] Bhattacharyya, R. (2015). A grey theory based multiple attribute approach for R&D project portfolio selection. Fuzzy Information and Engineering, 7(2), 211-225.

[4] Cheng, C. H., Liou, J. J., & Chiu, C. Y. (2017). A consistent fuzzy preference relation based ANP model for R&D project selection. *Sustainability*, 9(8), 1352.

[5] Jonas, D. (2010). Empowering project portfolio managers: How management involvement impacts project portfolio management performance. *International Journal of Project Management*, *28*(8), 818-831.

[6] Blichfeldt, B. S., & Eskerod, P. (2008). Project portfolio management–There's more to it than what management enacts. *International Journal of Project Management*, *26*(4), 357-365.

[7] Mikkola, J. H. (2001). Portfolio management of R&D projects: implications for innovation management. *Technovation*, *21*(7), 423-435.

[8] Abbassi, M., Ashrafi, M., & Tashnizi, E. S. (2014). Selecting balanced portfolios of R&D projects with interdependencies: A Cross-Entropy based methodology. *Technovation*, 34(1), 54-63.

[9] Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (1997). Portfolio management in new product development: Lessons from the leaders-I. *Research-Technology Management*, *40*(5), 16-28.

[10] Martino, J. P. (1995). *Research and development project selection*. Wiley.

[11] Liberatore, M. J., & Titus, G. J. (1983). The practice of management science in R&D project management. *Management Science*, *29*(8), 962-974.

[12] Coldrick, S., Lawson, C. P., Ivey, P. C., & Lockwood, C. (2002, August). A decision framework for R&D project selection. In *IEEE International Engineering Management Conference* ,1, 413-418, IEEE.

[13] RezaHoseini, A., Ghannadpour, S. F., & Hemmati, M. (2020). A comprehensive mathematical model for resource-constrained multi-objective project portfolio selection and scheduling considering sustainability and projects splitting. *Journal of Cleaner Production*, 122073.

[14] Wannakul, R., Pathumnakul, S., & Arunyanart, S. (2019, October). Factors Affecting Decision to Select Government R&D Support Projects for SMEs. In *IOP Conference Series: Materials Science and Engineering*, 639(1), 012011, IOP Publishing.

[15] Gonçalves, E.D.C. (2019). Criteria Used in Research & Development Project Selection, Master's degree in Industrial Engineering.

[16] Karasakal, E., & Aker, P. (2017). A multicriteria sorting approach based on data envelopment analysis for R&D project selection problem. *Omega*, *73*, 79-92.

[17] Markowitz, H. (1952). Portfolio selection. Journal of Finance ,7, 77–91.

[18] Rubinstein, R. Y. (1997). Optimization of computer simulation models with rare events. *European Journal of Operational Research*, *99*(1), 89-112.

[19] Caserta, M., & Nodar, M. C. (2009). A cross entropy based algorithm for reliability problems. *Journal of Heuristics*, *15*(5), 479.

[20] Huang, C. C., & Chu, P. Y. (2011). Using the fuzzy analytic network process for selecting technology R&D projects. *International journal of technology management*, *53*(1), 89-115.

[21] de Gracia, M. D. S., Perrino, D. M., & Llamas, B. (2019). Multicriteria methodology and hierarchical innovation in the energy sector. *Management Decision*.

[22] Pererva, P., Besprozvannykh, O., Tiutlikova, V., Kovalova, V., Kudina, O., & Dorokhov, O. (2019). Improvement of the Method for Selecting Innovation Projects on the Platform of Innovative Supermarket. *TEM Journal*, *8*(2), 454.

[23] Kütükçü, A. Z., & Eren, T. (2017). Acil durum haberleşmesinde kullanılan el telsizinin çok ölçütlü karar verme yöntemleri ile seçilmesi. *Selcuk University Journal of Engineering, Science and Technology*, 5(2), 183-203.

[24] Yildiz, A., & Yayla, A. Y. (2015). Multi-criteria decision-making methods for supplier selection: A literature review. *South African Journal of Industrial Engineering*, *26*(2), 158-177.

[25] Yıldız, A. (2014). En iyi üniversite seçiminde analitik ağ prosesinin kullanımı. *Düzce Üniversitesi İleri Teknoloji Bilimleri Dergisi*, *3*(2), 108-119.

[26] Yildiz, A. (2019). Green supplier selection using topsis method: a case study from the automotive supply industry. *Journal of Engineering Research and Applied Science*, *8*(2), 1146-1152.

[27] Özcan, E. C., Ünlüsoy, S., & Eren, T. (2017). ANP ve TOPSIS yöntemleriyle Türkiye'de yenilenebilir enerji yatırım alternatiflerinin değerlendirilmesi. *Selçuk Üniversitesi Mühendislik, Bilim ve Teknoloji Dergisi*, *5*(2), 204-219.

[28] Yıldız, A., & Özbek, A. (2020). Selection of socks export markets for Turkey using multicriteria decision making methods. *Sigma: Journal of Engineering & Natural Sciences/Mühendislik ve Fen Bilimleri Dergisi*, *38*(2), 795-815.

[29] Beğik, M., Hamurcu, M., & Eren, T. (2017). Stok kontrolde ABC analizi ve analitik ağ süreci yönteminin ısı cihazları firmasında uygulanması. *Kırıkkale Üniversitesi Sosyal Bilimler Dergisi*, *7*(1), 197-216.

[30] Saaty, T.L. *Theory and Applications of the Analytic Network Process*, USA: RWS Publications, 2005.

[31] Saaty, T.L. *The ANP for Decision Making with Dependence and Feedback*, USA: RWS Publications, 1996.

[32] Balaban, Y., & Baki, B. (2010). Analitik ağ süreci yaklaşımıyla en uygun katı atık bertaraf sisteminin belirlenmesi: Trabzon ili örneği. *Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi*, 24(3), 183-194.

[33] Baynal, K., & Yüzügüllü, E. (2013). Tedarik zinciri yönetiminde analitik ağ süreci ile tedarikçi seçimi ve bir uygulama. *İstanbul Üniversitesi İşletme Fakültesi Dergisi*, 42(1), 77-92.