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RESEARCH ARTICLE

ANALYSIS OF PROBLEMS EXPERIENCED IN ECO-INDUSTRIAL PARK INSTALLATION BY ANP METHOD

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ABSTRACT

As the population increases rapidly in the world, the needs of people increase at the same rate, trying to supply the needs of people. On the other hand, supplying needs raises the problem of consumption of limited resources. In this study, the installation of eco-industrial parks, one of the clean production and recycling studies developed due to the consumption of resources, was discussed. Eco-industrial parks are industrial zones established to increase enterprises' economic, social, and environmental performance and gain ordinary profits through cooperation. In this study, the difficulties of setting up an eco-industrial park were identified through a literature review. Purpose of the study; eco-industrial park installations to be realized smoothly, existing problems before the installation of the eco-industrial park to be identified as the most critical problems, identified issues to be solved, and support to maintain. The criteria determined were evaluated by the ANP method, and the most important criterion was financial problems.

Keywords: Industrial symbiosis, Analytical network process, Eco-industrial park

1. INTRODUCTION

The need for resources is also increasing with industrialization and population. To meet the need for resources, an increase in production, consumption, and environmental pollution accompanied by production has begun. Pollution and consumption growth have also made people, businesses, and states aware of the cyclical economy. The circular economy consists of recycling systems that protect the environment and prevent the consumption of resources [1]. One of these systems is the concept of Industrial Symbiosis (IS). Symbiosis is a relationship in which two or more species benefit and transfer energy, matter, or information to each other [2]. IS is a system in which companies cooperate in an industrial sense and provide mutual benefits to each other [3]. With IS, one company can use the waste of another company as a raw material. Thanks to this, inter-company cooperation increases, waste decanted into the environment decreases, and resource efficiency increases.

With these mutually beneficial partnerships in enterprises, waste, and by-products are recovered, savings are achieved in resource use, and raw materials and energy are used efficiently to reduce environmental emissions. The concrete application of industrial symbiosis approaches is Eco-Industrial Parks. Sustainable and clean production is targeted in these practices [4].

Eco-industrial parks are resource exchange applications that occur with the cooperation of enterprises geographically close to each other, even though they are independent in an industrial zone. Industrial plants that are independent of each other and preferably located close to each other form a coexistence. The total benefit to be obtained by working together will be more than the sum of the benefits based on the business that the businesses will obtain by optimizing their functioning only [5]. This application, which is very important and profitable for enterprises and resource efficiency, requires material flow

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analysis, determining the measures to be taken within the facilities, and eliminating system inefficiencies [6]. However, some problems may occur in accordance with these requirements. Therefore, this study discusses the problems that may be experienced in the eco-industrial park installation process. Looking at the literature, there are many studies on the installation and application of eco-industrial parks. In this study, problems that need to be addressed before installation and applications and that need to be solved before installation have been identified, and priority values of the problems have been calculated. Due to the quantitative structure of the study, it differs from other studies in the literature. This study aimed to identify the most critical problems to identify and solve before the installation was started. While eco-industrial parks have emerged on the concept of sustainability, these parks should also be sustainable. Ensuring this situation is possible by taking solid steps in the first stage when the system is just beginning to be established. Therefore, this study's primary purpose and motivation is to avoid the problems encountered in light of the criteria determined during the planning stage of the installation of these applications and to proceed with solid steps. The studies in the literature were examined, and the criteria that were effective on the problem were determined. These criteria were evaluated by the ANP method. The power of the ANP method to evaluate the interaction and relationships between the criteria was utilized. By converting the qualitative evaluations into quantitative values, the priority values of the criteria that caused the problems encountered during the establishment of eco-industrial parks were calculated. This study answers how businesses that turn to eco-industrial parks due to the environmental damage caused by industrial parks can establish a more accessible system today when sustainability is important. In this respect, contributions are made to businesses and the literature.

This study consists of six parts. In the second part, eco-industrial parks are explained. In the third part, studies in the literature are given. In the fourth part, the method used is explained. Numerical results are also included in the fifth part. In the last part, the obtained results are interpreted.

2. ECO-INDUSTRIAL PARKS

Industrial ecology aims to balance industrial development with the sustainable use of natural resources to develop environmentally friendly production and consumption. On the other hand, ensuring the relationship between society, the economy, and the environment focuses on issues such as protecting renewable resources, carefully using energy, and recycling [7]. Many enterprises aimed at industrial ecology are established at a close distance from each other and in a connected way [8]. Due to the connections between enterprises, industrial zones are transformed into industrial ecosystems. These connections are also called IS [9].

An IS is an approach based on mutual benefit between industries. It is when at least two enterprises working independently, although physically close to each other, establish relations that can improve environmental performance and competitiveness [10]. Some applications of IS have been developed in eco-industrial parks, and these eco-industrial parks are seen as concrete facts of the concept of IS [3].
The eco-industrial park is a community of companies in the production and service sectors that want to improve their environmental and economic performance by cooperating in managing the environment and resources (energy, water, and matter) [11]. Eco-industrial parks aim to reduce the flow of materials and energy and environmental impacts, ensuring profit and common benefit in the economic and social development of facilities close to each other.

An eco-industrial park;

- From a by-product exchange model or exchange network,
- From a recycling business group (resource recovery or recycling companies,
- From all environmental technology companies,
- Green product manufacturing companies,
- An industrial park designed around a single type of environmental theme (solar-powered park),
- From a park with an environmentally friendly infrastructure or structure,
- Industrial, commercial, or local, mixed-use development

there should be more [8].

It is helpful to organize a further study of industrial projects with the exchange of materials; to think differently, although it is suggested by industrial ecology. Chertow proposed five different eco-industrial park models in his study. These recommendations are presented in Table 1.

Table 1. 5 Eco-industrial park models proposed by Chertow [8]

Model	Explanation
Exchange through waste exchanges	In this model, enterprises give their waste to recycling facilities. The waste exchange is one-sided, and there is no energy exchange with water. Since it is an old and traditional method, it is the most distant model to the definition of IS.
An exchange within a facility, company or organization	In this model, an enterprise acts as a separate enterprise to its subunits and provides between units. In this way, profits can be made on purchases and product designs.
An exchange between companies located in a defined eco-industrial park	In this model, water, energy, and material exchange is carried out between companies and organizations in the eco-industrial park. Relations can be established not only between companies in the park but also with organizations outside the park.
Exchange between local firms that are not placed side by side	In this model, exchanges take place between businesses in a region. Although they are not neighbors, a symbiotic relationship be established between businesses with geographical proximity.
Exchange between companies organized in a wider region	In this model, a virtual connection is established between businesses not located in the same region, and item exchanges are performed. However, the options are not unlimited due to shipping costs.

3. LITERATURE RESEARCH

In recent years, the effects and causes of climatic and environmental changes in the world have increased awareness of sustainability. IS is one of the methods considered to be the key strategy that promotes the sustainable use of resources. IS is mainly based on the principle that the waste produced by one company can be used by other companies to replace production inputs or to produce new products [1].

Since the late 1990s, different studies have been carried out on the planning and design of industrial zones that have adopted an IS approach. As a result, industrial diversity and cooperation are ensured in industrial zones and industrial parks thanks to the work done. As a result, energy and water efficiency are maximized, and waste formation and environmental effects caused by waste are minimized; systems can be established in which companies' economic performance increases, product diversity and economic competition increase, and sustainable industrial zones are created [6].

Many studies have been carried out to evaluate systems in existing industrial parks. Economic growth and environmental protection have been critical issues in facilitating the development of eco-industrial parks in China. As the main contributors to China's industrial production, many industrial parks address issues of intensive resource consumption and pollutant production driven by stricter environmental and resource management regulations [12]. In Chinese industrial parks, the central wastewater treatment plant is a critical shared infrastructure for further purification of pre-treated industrial wastewater on-site [13]. In another study conducted in China, they prioritized the benefits of eco-industrial parks by considering their benefit criteria and evaluating them with Gray-Delphi and VIKOR methods [14]. An IS application has been developed in Turkey, which also carries out wastewater treatment and where a

zero-waste process takes place, where the useful use of the waste of one of the two different sectors as the raw material of the other is revealed [15].

In addition to the evaluation studies in the literature, there are also different studies. In one of these studies, a Clean Production and IS decision support platform were implemented with the support of the EU project with the partnership of Turkey-Switzerland. As a result of the studies carried out for this platform, a decision support platform was designed and developed, and case analyses were shared through the platform [16]. In another study, the potential for transforming organized industrial zones and industrial zones into eco-industrial parks is expected to be the most suitable means for foreign capital investments to enter our country and become permanent by turning them into significant investments, has been studied [17]. In a study conducted in Şanlıurfa, companies in the Organized Industrial Zone were examined, and the alternatives to converting this industrial zone into an industrial eco-park were examined. In addition, a survey study on waste has been carried out for companies, and it has been aimed to form the basis of waste assessment systems for the industrial zone [18].

To support decision-makers who wish to establish and operate an IS network, Analytical Network Process and the criteria to be considered and their importance was calculated with the method of analytical hierarchy process [19].

This study focuses on the criteria that cause problems in establishing eco-industrial park applications that will be designed to reduce the harmful effects of the industry on the environment. Making the evaluation of these criteria with the ANP method, taking into account the interaction and relationship between the criteria, contributed positively to the construction of the establishment process of the enterprises in terms of literature review and real life. In addition, it also contributes to the literature by emphasizing the things that should be considered in the light of the criteria to avoid possible problems that may be encountered at the planning stage.

4. MATERIALS AND METHODS

The decision constantly evolves, but it is a selection process made from among the available options, adhering to at least one goal and criterion. At this selection stage, Multi-Criteria Decision-Making (MCDM) methods are used to make the correct decision. MCDM methods, in which binary comparisons of the criteria that have been determined are usually based, contribute to making the right decision through numerical data and in the future [20].
In this study, the problems likely to occur in the eco-industrial park installation were determined with the help of other literature studies. The criteria priority values were calculated using the Analytical Network Process method. The study aims to support the smooth implementation and maintenance of eco-industrial park installations.

4.1. Analytical Network Process Method (ANP)

The ANP developed by Saaty allows more complex relationships between decision levels and features to be taken into account [21].

Stages of the Analytical Network Process Method:

1. Stage: The decision-making problem is determined.
2. Stage: The relationship of the criteria with each other is determined.
3. Stage: Decoupling comparisons are made between the criteria.
4. Stage: The consistency of the comparison matrices is checked.
5. Stage: Super-matrices are created.
6. Stage: The best alternative is determined and the choice is made [22].

In the ANP method, the level of criteria influence on each other is indicated by a network that matches the nodes [23]. Criteria in a node can affect some or all of the criteria in any other node. The established relationships are indicated by arrows in the network structure, and the direction of the arrows, the dependence between the nodes [24-25]. The dependence between two nodes is called an "external dependence" and is indicated by a two-way arrow. In contrast, the dependencies between the lower criteria within a node are called "internal dependence" and are indicated by the arrow as a loop. Considering the studies on ANP in the literature, [26] in performance evaluation, [27], [28], [29], are seen in energy to study.

5. RESULTS

5.1. Defining The Problem

With the industry's progress, the world's natural balance has also begun to deteriorate, leading to many other problems, such as global warming and climate change. Therefore, people have also started to take measures for these problems and to work to make the production in the industry cleaner. Some of these studies aim to increase the industry's resource efficiency, renewable energy sources, and labor productivity. In these studies, the industry has emerged concepts such as clean production, industrial ecology, and eco-industrial park. Eco-industrial parks are systems that target clean production and zero waste so that problems will cause away from the target. In parks that are not well designed and do not have strong management, resource efficiency cannot be achieved, and costs increase in waste disposal. In these cases, there are problems in the establishment of eco-industrial parks. Therefore, it is necessary to identify and solve the problems that may occur in the installation of the park. In this study, the criteria that may occur during the installation of an eco-industrial park have been identified by examining other studies in the literature and the requirements and regulations for installing an eco-industrial park. The criteria identified were evaluated using the ANP method, which is one of the MCDM methods. The flow chart of the study is shown in Figure 1. The criteria and their description are found in Table 2. Table 2 also shows the criteria categorized as main and sub-criteria.

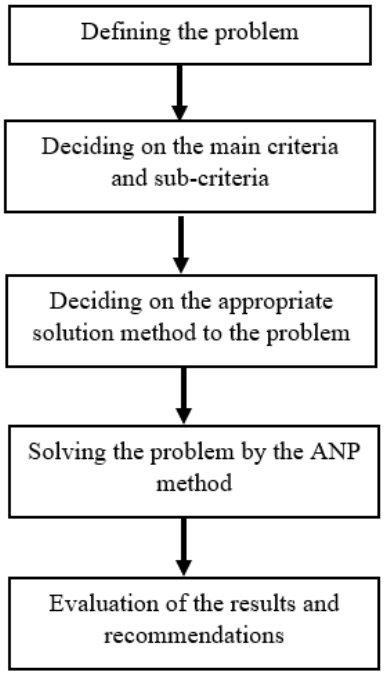

Figure 1. The flow chart of the study

Table 2. Criteria and descriptions

Main Criteria	Sub-Criteria	Explanation
Organizational Barriers (OB)	Competition	Inter-company races with similar aspects, decoupling.
	Distrust Between Firms	The state of trust between firms that do not know each other decently or know each other incorrectly.
	Location of the Park	It is the geographical location of the current or upcoming park.
	Transportation Facilities	The transportation facilities of the park are such facilities as the surrounding land road, sea road, air road.
Legal Barriers (LB)	Lack of Information	Lack of knowledge about IS, recycling, eco-industrial parks and laws.
	Compliance with International Standards	Compliance with the necessary standards for the installation of an eco-industrial park.
Economic Barriers (EB)	Financial Problems	Financial support will be provided to companies that will establish an IS network.
	Infrastructure Expenditures	Necessary infrastructure costs for park installation or recycling works.
Technological Barriers (TB)	Lack of Infrastructure	The lack of requirements for the installation of an IS network and an eco-industrial park.
	Lack of Hardware	It is the lack of equipment that enterprises or the park have.
Institutional Barriers (IB)	Available Recycling Facilities	These are recycling facilities that companies own, cooperate with other enterprises, or produce by recycling.
	Disbelief in the Usefulness of the System	It is the idea of not being able to benefit institutionally from the concept of EIP.
	Non-Compliance with the Concept	If there is a concept of a park that exists or is planned to be established; this is a case of non-compliance with the concept.

5.2. Solving The Problem

The problem was solved by the ANP method. The ANP method, developed by Thomas L. Saaty, is a decision-making method that considers the relationships between the criteria at the decision stage and eliminates the need for one-way modeling of the problem. Because it considers the relationships between the criteria and facilitates the solution of complex problems, this method was preferred when analyzing the problems experienced in installing an eco-industrial park. By examining the literature, the criteria that were effective on the problem were determined. The network structure was created by considering these criteria' relationships, interactions, and feedback [30]. Pairwise comparison matrices were established according to the network structure and relations. In paired comparison matrices, how effective the criteria are relative to each other was determined using Saaty's 1-9 [31] scale.
Figure 2 shows the network structure established in the study.

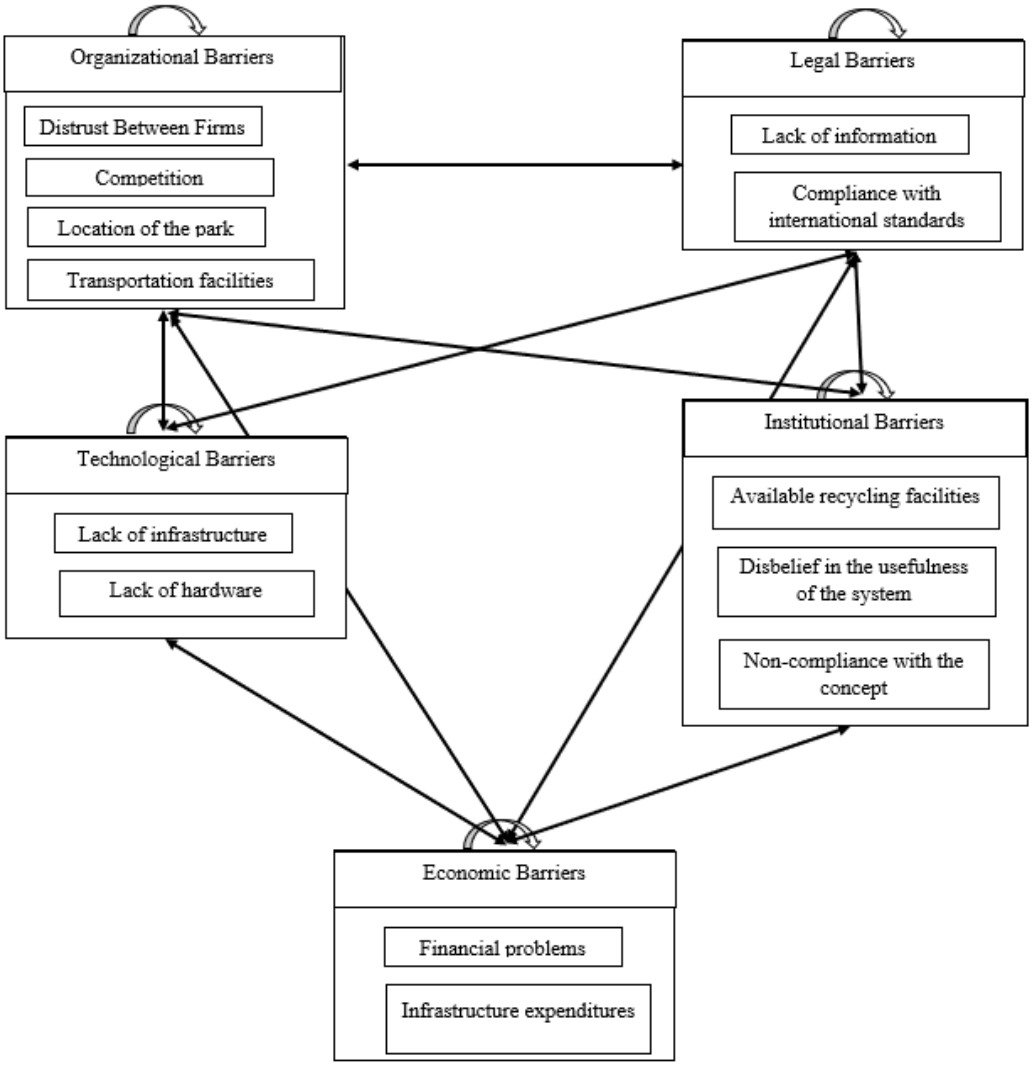

Figure 2. Network structure established according to the ANP method

5.3. Evaluation of the Solution Method

In the ANP method, pairwise comparison matrices are created between the criteria in a relationship. Table 3 shows the pairwise comparison matrix of the main criteria, the legal barriers criterion, as an example. Table 4 shows the criteria weights obtained from the evaluations of all pairwise comparison matrices. Table 4 shows the priority values calculated for the criteria.

Table 3. Comparisons for the main criterion of legal barriers

EB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	IE
EB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	OB
EB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	TB
EB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	LB
IB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	OB
IB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	TB
IB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	LB
OB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	TB
OB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	LB
TB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	LB

Table 4. Calculated priority values for the criteria

Main Criterias	Criteria Weights	Sub-Criteria	Sub-Criteria Weights
Organizational Barriers (OB)	0.195	Competition	0.153
		Distrust Between Firms	0.545
		Location of the Park	0.172
		Transportation Facilities	0.130
Legal Barriers (LB)	0.470	Lack of Information	0.460
		Compliance with International Standards	0.540
Economic Barriers (EB)	0.122	Financial Problems	0.673
		Infrastructure Expenditures	0.327
Technological Barriers (TB)	0.136	Lack of Infrastructure	0.635
		Lack of Hardware	0.365
Institutional Barriers (IB)	0.077	Available Recycling Facilities	0.483
		Disbelief in the Usefulness of the System	0.229
		Non-Compliance with the Concept	0.288

According to the priority values resulting from the ANP method, the most important criteria/problems are financial problems, lack of infrastructure, distrust between companies, compliance with international standards, and existing recycling facilities. The five most important sub-criteria also belong to different main criteria. These main criteria are, respectively: economic barriers, technological barriers, organizational barriers, legal barriers, and institutional barriers. If these main criteria are also sorted by their degree of importance, respectively, it is seen that there are legal barriers, organizational barriers, technological barriers, economic barriers, and institutional barriers. In this case, the solution to problems should start from the main criteria with the highest priority value and the most important sub-criteria of these main criteria.

6. CONCLUSIONS

IS is based on the principle that the output of one company can be used as production input by other companies. Eco-industrial parks, one of the applications of IS, coexist on common property and are defined as a community of production and service industries that can exchange waste with each other, allowing enterprises to increase their social and individual benefits.

When literature studies are examined, IS strategies are determined, criterion weights for EIP installation are calculated, EIP potential calculations are performed, and different IS applications are observed. This study differs from other studies in identifying and analyzing problems that may occur in installing EIP.

This study identifies problems likely to occur during the installation process of eco-industrial parks. These problems have been solved with ANP from MCDM methods. The ANP method supports the study in terms of establishing a relationship between criteria, and the problems should be addressed in accordance with the results obtained from the method. Organizational barriers, legal, economic, technological, and institutional barriers, including 5 of 13 covered by these criteria, the main criteria and sub-criteria, and priority of the relations established between the ANP method by calculating the values of the solution have been reached. The results from this study; EIP was taken for a region that

will be set up; the problems identified to prevent possible problems, speed up the installation process, eliminate the costs of subsequent projects, and aims to be a reference for error. Therefore, before establishing an eco-industrial park in a region, possible problems should be examined. Thus, a smooth installation can be achieved. It contributes to sustainable production and the protection of natural resources and provides benefits and expected benefits in enterprises' economic and social development.

These problems consist of the sub-criteria used in the solution of the ANP method. The solution results show that legal barriers are the main criteria. Financial problems, lack of infrastructure, and distrust between companies are the criteria with the highest priority values. Priority should be given to the sub-criteria under the main criterion of legal barriers, and firms should have information about IS and EIP. In addition, international standards should be investigated and made compliant with the standards. Other important sub-criteria also indicate the improvements and innovations the enterprise must make before an eco-industrial park is established. Since being located in an eco-industrial park means a large environmental investment, enterprises need to minimize their financial problems and prepare for the necessary infrastructure. Eco-industrial parks require cooperation between companies, so the necessary attention should be paid to competition, which is one of the most important. The distrust between companies should also be eliminated. In future studies, these criteria can be evaluated using fuzzy multi-criteria decision-making methods. In addition, the parks established in the light of these criteria can be evaluated.

CONFLICT OF INTEREST

The authors stated that there are no conflicts of interest regarding the publication of this article.

AUTHORSHIP CONTRIBUTIONS

Edanur Sonel: Formal analysis, Writing - original draft, Visualization. Şeyda Gür: Formal analysis, Investigation. Tamer Eren: Supervision, Visualization, Conceptualization.

REFERENCES

[1] Genç O. Sustainable eco-industrial park development and design inspired by nature. (PhD). Iskenderun Technical University / Institute of Engineering and Natural Sciences, Hatay, 2020.

[2] Yıldız Ö. Applications of industrial symbiosis in regional development: an example of the Bursa Eskişehir Bilecik Region. (Master). Uludag University, Bursa, 2019.

[3] Chertow MR. Uncovering industrial symbiosis, Journal of Industrial Ecology 2007; 11(1): 11-30. https://doi.org/10.1162/jiec.2007.1110.

[4] Yazıcı E, Alakaş HM, Eren T. Analysis of operations research methods for decision problems in the industrial symbiosis: a literature review, Environmental Science and Pollution Research 2022; 29(47): 70658-70673.

[5] Alakaş HM, Gür Ş, Özcan E, Eren T. Ranking of sustainability criteria for industrial symbiosis applications based on ANP, Journal of Environmental Engineering and Landscape Management 2020; 28(4): 192-201.

[6] Özkan A, Günkaya Z, Özdemir A, Banar M. Industrial symbiosis approach in the transition to clean production and a circular economy in industry: an evaluation, Anadolu University Journal of Science and Technology-B Theoretical Sciences 2018; 6(1): 84-97. https://doi.org/10.20290/aubtdb.332377

[7] Van Berkel R, Willems E, Lafleur M. Development of an industrial ecology toolbox for the introduction of industrial ecology in enterprises, Journal of Cleaner Production 1997; 5(1-2): 11-25. https://doi.org/10.1016/S0959-6526(97)00004-8

[8] Chertow MR. Industrial symbiosis: literature and taxonomy, Annual Review of Energy and The Environment 2000; 25(1): 313-337. https://doi.org/10.1146/annurev.energy.25.1.313

[9] Giurco D, Bossilkov A, Patterson J, Kazaglis A. Developing industrial water reuse synergies in port melbourne: cost effectiveness, barriers and opportunities, Journal of Cleaner Production 2011; 19(8): 867-876. https://doi.org/10.1016/j.jclepro.2010.07.001

[10] Kılıç İ, Delice H, Sofu S, Yıldız B. Application of industrial symbiosis in livestock enterprises: an example of Bursa, Journal of Faculty of Agriculture 2018; 240-248.

[11] Ulutaş F. Industrial ecology, Sustainable Production and Consumption Publications –VI. 2016. Erişim adresi: http://www.rec.org.tr

[12] Hu W, Tian J, Chen L. An Industrial structure adjustment model to facilitate high-quality development of an eco-industrial park, Science of the Total Environment 2021; 766: 142502. https://doi.org/10.1016/j.scitotenv.2020.142502

[13] Hu W, Tian J, Li X, Chen L. Wastewater treatment system optimization with an industrial symbiosis model: a case study of a Chinese eco-industrial park, Journal of Industrial Ecology 2020; 24(6): 1338-1351. https://doi.org/10.1111/jiec.13020

[14] Zhao H, Zhao H, Guo S. Evaluating the comprehensive benefit of eco-industrial parks by employing multi-criteria decision-making approach for circular economy, Journal of Cleaner Production 2017; 142: 2262-2276. https://doi.org/10.1016/j.jclepro.2016.11.041.

[15] Eroğlu Önpeker S. Development of an industrial symbiosis application for the evaluation of heavy metal-containing electrocoagulation waste. (Master). Anatolian University, Eskişehir, 2017.

[16] Gümüş TÇ. Development of a clean production and industrial symbiosis decision support system for eco-industrial parks, (Master). TOBB ETÜ, Ankara, 2016.

[17] Güder E. Transformation of organized industrial zones and industrial zones in Turkey into eco-industrial parks, V. National Productivity Congress, Ankara-Türkiye, 2013.

[18] Kasar N. Investigation of the potential of Sanliurfa organized industrial zone to be transformed into an industrial eco-park. (PhD). Harran University, Şanlıurfa, 2013.

[19] Şen E. An analytical network process approach for creating an industrial symbiosis network. (Master). Hacettepe University, Ankara, 2019.

[20] Evren R, Ülengin F. Multi-purpose decision making in management. Publications of Istanbul Technical University, 1992.

[21] Meade LM, Sarkis JJIJ. Analyzing organizational project alternatives for agile manufacturing processes: an analytical network approach, International Journal of Production Research 1999; 37(2): 241-261.

[22] Sonel E, Gür Ş, Eren T. City selection and analysis in health tourism with multi-criteria decision making, International Journal of Global Tourism Research 2019; 3(1): 27-39.

[23] Büyükyazıcı M. The process of analytical networking. dissertation of the specialty of science. Hacettepe University Institute of Natural and Applied Sciences Department of Statistics, Ankara, 2000.

[24] Saaty TL. Decision making with dependence and feedback: The Analytic Network Process (Vol. 4922). Pittsburgh: RWS publications, 1996.

[25] Dağdeviren M, Eraslan E, Kurt M, Dizdar EN. An alternative approach to the supplier selection problem with the analytical network process, Technology 2005; 8(2): 115-122.

[26] Saputro KEA, Karlinasari L, Beik IS. Evaluation of sustainable rural tourism development with an ıntegrated approach using MDS and ANP methods: case study in Ciamis, West Java, Indonesia, Sustainability 2023; 15(3): 1835.

[27] Yitmen I, Al-Musaed A, Yücelgazi F. ANP model for evaluating the performance of adaptive façade systems in complex commercial buildings. Engineering, Construction and Architectural Management 2021; 29(1): 431-455.

[28] Zhang K, Liang X, Wei H, Liu S, Su K. An improved TOPSIS-ANP composite shielding material performance evaluation method based on gray relational projection algorithm, Frontiers in Energy Research 2023; 10.

[29] Purwani F. An analytic network process method approach to design models of lecturers performance evaluation, International Journal of Artificial Intelligence Research 2023; 6(1.2).

[30] Ersöz F, Kabak M. A literature review of multi-criteria decision-making methods in defense industry applications, Journal of Defense Sciences 2010; 9(1): 97-125.

[31] Saaty TL. Deriving the AHP 1-9 scale from first principles, Proceedings 6th ISAHP. Berna, Suiza 2001; 397-402.