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Analysis of the Difficulties of SMEs in Industry 4.0 Applications by Analytical Hierarchy Process and Analytical Network Process

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Abstract: The concept of Industry 4.0 is seen as a recent paradigm in the manufacturing sector. The use of new production and management technologies required by the concept of Industry 4.0 is very important for small enterprises in order to keep up with the competition. However, most enterprises look at these requirements in a negative way. This study analyzes the propulsion forces of Industry 4.0 adopted in small and medium enterprises. By analyzing the difficulties in the transition process of small and medium-sized enterprises (SMEs) to Industry 4.0, the company contributes to the determination of strategic steps taking these results into consideration. This will facilitate the transition of enterprises to Industry 4.0 and progress can be made towards efficient use of resources. A hierarchical structure was established under the four main criteria of innovation, organization, environmental, and financial aspects, and the relative weight of these criteria and sub-criteria were calculated. The surveys conducted on business managers were evaluated using multi-criteria decision-making methods by the analytic hierarchy process method and the analytic network process. At the same time, the interaction between these criteria was taken into consideration and the criteria were re-evaluated by the analytical network process method. The results of the two methods seem to support each other.

Keywords: small and medium enterprises; Industry 4.0; multi-criteria decision making; analytic hierarchy process; Analytic network process

1. Introduction

Industrial automation and the production of highly mechanized products are among the expectations for the future of the Industry 4.0 revolution. Applications such as Kanban and Six Sigma, which are used to increase productivity in production processes, are now combined with technology and contribute to the development and change of the enterprise. The concepts and applications that can be considered as old are brought to the top with new technological developments [1,2]. The most important effects of Industry 4.0 are the use of technology, production of big data architecture, and analysis of these data. Using information technologies in production and services, small and medium-sized enterprises (SMEs) will have a significant impact on the orders received [3]. Enterprises adapting to this technology, to integrate into production processes cause competition in the market. Enterprises that integrate technology into the production line will lead to intelligent operation of the line, and even automation of maintenance and support processes, resulting in intelligent maintenance processes [4]. Thus, it will be possible to proceed in a planned manner with these smart systems. With the reduction of the related costs and the reduction of the failures, operation of the enterprise at optimum capacity will be ensured [5].

Nowadays, businesses are rapidly growing in order to integrate Industry 4.0 concepts. Innovations and studies with the introduction of the concept of Industry 4.0 are increasing [6]. Researchers often refer to the practices and innovations that this concept brings with it. In the literature, Shrouf et al. [7] carried out an evolutionary journey towards the concept of Industry 4.0. In the study which contains the analysis of the existing enterprises' enterprises, the necessary infrastructures are mentioned in the Industry 4.0 transition process. They also included the expected benefits of Industry 4.0. Stock and Seliger [8] highlighted the growing demand for consumer goods and the difficulties in meeting these demands. They talked about opportunities in Industry 4.0 for sustainable production. Hermann et al. [9], Liao et al. [10], and Lu [11] pointed to the recent advances in the Industry 4.0 revolution. They examined the studies for the industry in the literature and determined the subject areas and categories. They included the current research activities. It also provides a definition of Industry 4.0 and defines design principles for its implementation. Xu et al. [12] took into account the industrial situation of countries since the emergence of the concept of Industry 4.0. They examined the state of the art technologies in relation to Industry 4.0. Organizations must digitize Industry 4.0 transition processes. For example, Schrauf and Berttram [13] describe the concept of digitalization in supply chain processes. Digitalization is based on basic technologies of organizations, how the supply chain can be adjusted in real time when the current process is changed, answers are required. Stating that Cyber Physical Production Systems (CPPS) systems are connected to the virtual world of global digital networks according to Internet of Things (IoT) concepts, Galleguillos et al. [14] emphasized that flexible and reconfigurable controllers of these systems should be implemented. For this aim, they made a recommendation based on the Fuzzy Analytical Hierarchy Processes (FAHP) methodology for the development of digital networks. When we look at the studies in general, it is seen that Industry 4.0 focuses on innovation and technology. They integrated different decision-making processes with different methodologies, giving them a perspective on evaluation processes. Ly et al. [15] aimed to analyze the factors affecting the creation of successful IoT system for enterprises, Erdogan et al. [16] to find the best strategy for the application of Industry 4.0, Yoon et al. [17] to analyze the important factors related to the innovation of business models by using Analytical Network Processes (ANP) technique, Erbay and Yıldırım [18] to the selection of technology on Industry 4.0 technologies, Keskin et al. [19] to model the preparatory stages of organizational processes. Kayikci et al. [20] who draw attention to open and interconnected logistics services provided by Industry 4.0 and new opportunities to promote cooperation in transportation, conducted strategic compliance studies within the scope of supply chain partners. Sambrekar et al. [21] provide an overview of the different maintenance strategies in the sector by combining the results and inferences obtained from the studies in the literature. They also provided useful tools for the selection of maintenance activities to realize the Concept of Industry 4.0.

These digital transformations in production will create a real-time, dynamic and self-organizing infrastructure. Thanks to this infrastructure, enterprises will be able to analyze customer expectations and reach their targets [3]. First of all, while SMEs incorporate technological processes into their bodies, they need to cope with concepts such as knowledge, strategy, and planning. With well-planned planning, the digital process can complement the integration of their business [22]. In addition to the benefits of Industry 4.0 and the examples of large enterprises, there are many SMEs currently experiencing difficulties in these processes. The continuous development of technology and the continuous increase of innovations make it difficult to monitor the enterprises. It also increases the complexity of how these processes can be implemented. The availability of technology for Turkey in recent years is very important. SMEs, which have a 99% share in the area of entrepreneurship in Turkey, have an important approach in terms of the development and sustainability of the industry [23]. In a fierce competitive environment influenced by the concepts of technology and automation, SMEs have an important function in terms of development of the economy and future development. In this context, it can be seen that SMEs, which cannot keep up with technological developments, cannot compete with other enterprises in the same sector [24]. SMEs, which are trying to integrate the innovations of Industry 4.0 into their processes, face different challenges. In this study, the challenges faced by SMEs in adopting Industry 4.0 innovations are discussed in terms of innovation, organization, environmental, and cost dimensions. Using the analytical hierarchy process and analytic network process from multi-criteria decision-making methods, the challenges faced by SMEs in adopting these practices were evaluated. Multi-criteria decision-making methods, which are effective in terms of analysis and evaluation, are effective tools for quantitatively considering qualitative concepts. In this study, the fourteen sub-criteria under four main criteria were analyzed. The aim of this study was to determine the main and sub-criteria for determining the factors that will serve the transition of SMEs to Industry 4.0 by using analytic hierarchy process (AHP) and ANP methods. With AHP and ANP methods, priority criteria are determined by determining the weight of the criteria which are subject to the difficulties experienced in the transition to Industry 4.0. Important factors are understood here. This will facilitate the transition of SMEs Industry 4.0 and resources will be used more efficiently. These methods give the SME managers an idea to identify the priority criteria, and will guide the institutions that support SMEs, especially in the project evaluation on Industry 4.0. Thus, these institutions will be able to make a healthier decision in making plans for Industry 4.0 and support the right enterprises.

This study basically consists of five parts. In the second part, the scope of Industry 4.0 and its place in the literature are mentioned. In the third part, the methods used in the study and the applications of this method in the literature are given. In the fourth and fifth parts, the results obtained from the application and the application of the study are given.

2. Method

2.1. Analytical Hierarchy Process

The AHP method developed by Saaty [25] is an effective tool for assessing the criteria affecting the problem in intuitive decision-making environments. Through multi-level hierarchical structures, the criteria are scaled proportionally to each other by comparison matrices. The criteria/sub-criteria that are effective on the problem are modeled with a hierarchical structure. It has a simple and easy-to-implement solution process for evaluating these criteria together and qualitatively. There are basically four implementation steps used in the solution process of the AHP method [26].

Step 1. Defining the decision problem and establishing the hierarchical structure.

The structure of the problem is defined and the criteria affecting the problem are determined. A hierarchical structure consisting of more than one level is formed for the problem. For each problem, a hierarchical structure consisting of purpose, criterion, possible sub-criterion levels, and alternatives is established.

Step 2. Creation of comparison matrices between the criteria.

AHP determines the importance weights of the criteria by binary comparisons. When the binary comparison is done, the scale created by Saaty [25] is used. The scale values are shown in Table 1.

Table 1. 1–9 scale.

Importance Level	Definition
1	Equally important
3	One and the other partially
5	Basic or strong importance
7	Very powerful importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

Step 3. Calculation of the weight of the criteria.

The next stage of AHP is the creation of normalized matrices. The normalized matrix is obtained by dividing each column value by the respective column sum. Moving from the normalized matrix; the average of each sequence value is taken. These obtained values are the importance weights for each criterion.

Step 4. Checking the consistency ratios of the comparison matrices.

After obtaining the weights, the consistency of the comparison matrix should be considered. If the comparison matrix is not consistent, the resulting weights cannot be used. The vector (λ_{max}) that provides with equality ($A \times w = \lambda_{max} \times w$) should first be obtained. Where "A" is the comparison matrix, "w" is the weight matrix obtained. With the equation, the consistency index (CI) is obtained.

$CI = \frac{\lambda_{max} - n}{n-1}$ The value λ_{max} is obtained by dividing the weight vector by the respective relative values. After calculating the CI value, another value that needs to be obtained is the random index (RI). This value is tabulated for different matrix sizes. The RI values for different matrix sizes are shown in Table 2.

Table 2. Random index (RI) values.

n	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41
n	9	10	11	12	13	14	15	
RI	1.45	1.49	1.51	1.48	1.56	1.57	1.59	

Finally, a "consistency ratio (CR)" is obtained with the ratio of CI to RI. A CR of less than 0.1 indicates that the application is consistent. If this value is exceeded, the judgments should be reviewed again.

$CR = \frac{CI}{RI}$ Here, RI (random index) is the index of randomness. RI varies according to the n value (the size of the comparison matrix).

AHP method is an auxiliary solution that can be applied to the many problems encountered daily. Decision makers can make concrete and abstract assessments on alternatives/criteria/sub-criteria for many problems. The AHP method, which can be used wherever there is a decision making situation was preferred as an application tool as seen in the following examples; Ayan et al. [27] in the health sector, Alağaş et al. [28] in the communication sector, Özcan et al. [29] in the energy sector, Taş et al. [30] in portfolio management, Uçakcıoğlu and Eren [31] in the defense industry, Gür and Eren [32]; Hamurcu and Eren [33] in the transport and logistics sector, Alver et al. [34] in the education sector.

2.2. Analytical Network Process

Many of the decision-making problems include dependencies between factors and interactions within themselves. Saaty [35] proposed the ANP method to use for problems with internal or external dependencies between alternatives and criteria [36]. The ANP method consists of four stages [36]:

Step 1: Defining the problem and establishing the network structure.

The boundaries and the structure of the criteria are determined in this step. The network structure is formed according to the interactions, relationships, and feedback between the criteria. The aim, criteria, and sub-criteria are clearly expressed.

Step 2: Creation of binary comparison matrices.

According to the interactions established between the criteria and the sub-criteria within the defined decision problem, binary comparison matrices are made. Saaty's 1–9 [25] scale is used to compare the benchmarks between criteria. Table 1 shows the scale 1–9.

Step 3: Calculation of vector weights and consistency analysis.

In binary comparison matrices, all interactions between criteria/sub-criteria are taken into account. Equation ($A \times w = \lambda_{max} \times w$) is used in the calculation of vector weight. After the calculation of these values, a consistency analysis is performed as in AHP. This result, which is expected to be less than 0.1, indicates that the comparisons are meaningful and consistent.

Step 4: Create the super matrix.

Supermatrix structure is a matrix structure in which all interactions in the network structure are shown. Supermatrix, which has a fragmented matrix structure, contains vector weights derived from paired comparison matrices. It shows the relationship between two criteria/sub-criterion. The effect of criteria in a component on other criteria in the system is expressed by placing in the structure of supermatris.

ANP method has three kinds of supermatrix structure. These structures are called non-weighted, weighted, and limit matrix. The non-weighted supermatrix structure is the position of the priority values obtained from the binary comparison matrices in the matrix structure. After comparison in binary comparison matrices, relative priority values are obtained by comparing the associated clusters in the network structure with each other. With these priority values, the supermatrix structure weighted by the multiplication of the vector weights of the respective parts is obtained. The exponential forces are taken for convergence of the values in the obtained matrix structure. (2k + 1) by taking the number based in, the matrix values are converged to obtain a limit matrix structure. Here, k is a very large number.

The ANP method is currently used by researchers in many applications was preferred as an application tool seen in the following examples; Bag et al. [37]; Akça et al. [38] in the health sector, Hamurcu and Eren [39]; Hamurcu vd. [40]; Bedir et al. [41] in the transportation sector, Özcan et al. [42]; Özcan vd. [43] in the energy sector, Hamurcu and Eren [44] in the education sector.

3. Results

3.1. Application with AHP Method

With the integration of information and communication technology into production, smart product and smart machine concepts have come to the fore. Enterprises with these concepts have begun to activate their power in today's competitive environment. With these concepts which constitute the dimensions of Industry 4.0, significant advantages can be obtained in production and service processes in enterprises. However, in most enterprises, Industry 4.0 and prejudices against innovation have been created. They have difficulty adopting these concepts and adapting them to their business. In this study, the approaches of SMEs towards Industry 4.0 applications and the difficulties they face in these applications are examined. The criteria influencing these conditions are based on Premkumar and Roberts [45] studies in the literature. Criteria in the research model mentioned in the study were taken into consideration and then the criteria were expanded in consultation with SME experts and business managers. Industry 4.0, which offers new dimensions to SMEs, supports enterprises to strengthen their production and service processes with an increasing number of new technologies. SMEs who do not find themselves adequately equipped to face these new opportunities in their production and service processes have difficulties in these applications. The AHP method, which is one of the multi-criteria decision-making methods, has been evaluated for the criteria that are effective in these adoption processes. The solution process was continued according to the implementation steps of the AHP method.

Step 1. Defining the decision problem and establishing the hierarchical structure: In this study, it is planned to analyze the difficulties faced by SMEs in Industry 4.0 processes and applications. The criteria which are effective in these adoption processes were determined and the hierarchical structure of these criteria established. When determining the criteria, the study of Premkumar and Roberts [45] was used from the literature. In this study, innovation, organization, and environmental main criteria were taken into consideration. In the sub-criteria, relative advantages, complexity, relevance, top management support, organizational size, Information technologies (IT) expertise, competitive pressure, and external support sub-criteria were taken into consideration. Cost main criteria, recognition, intelligibility, distrust of benefits, cost of transition, maintenance and technical support, training and support cost sub-criteria are determined according to the opinions of experts. Figure 1 shows this hierarchical structure.

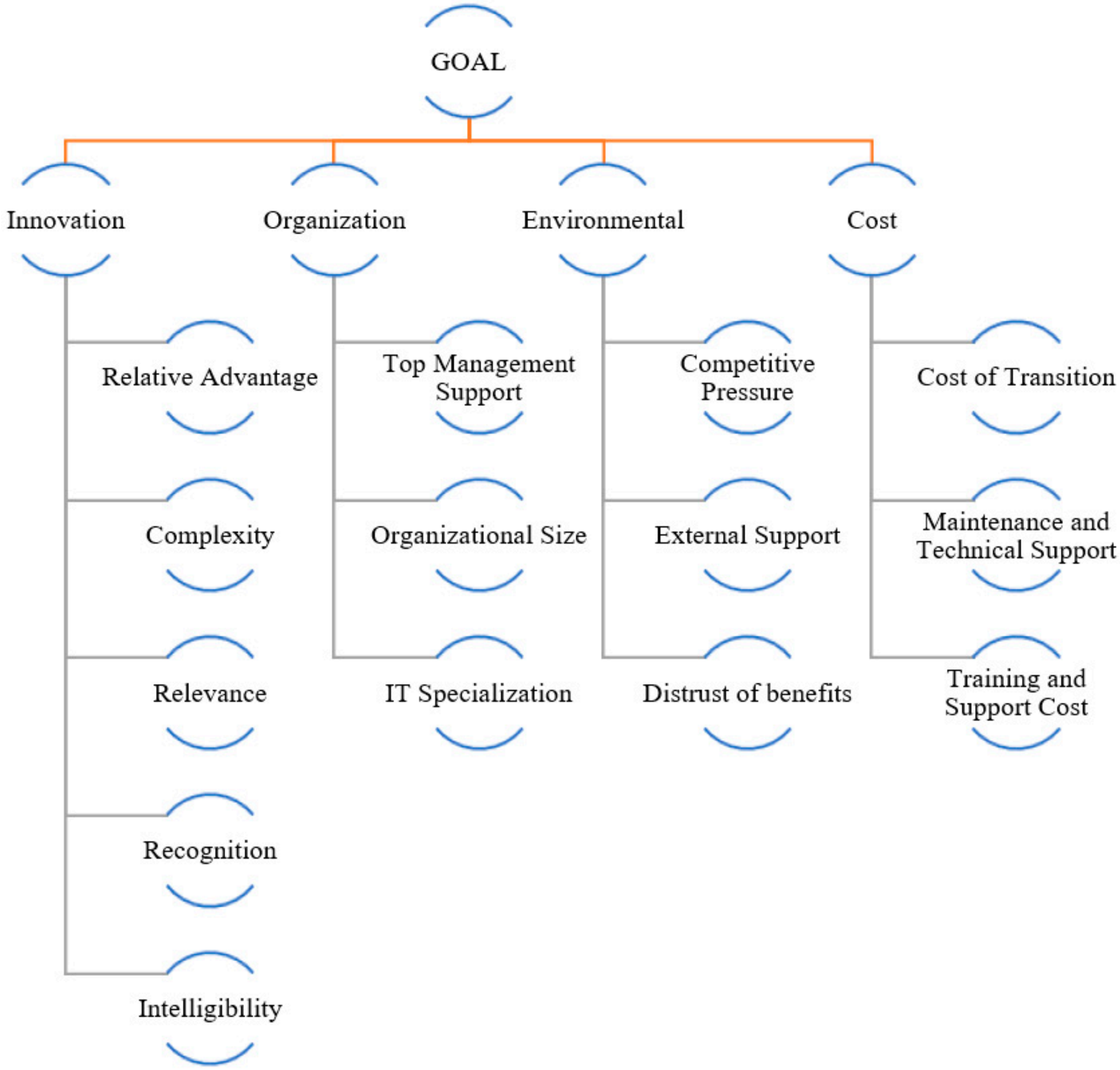

Figure 1. Hierarchical structure.

In Figure 2, there are 14 sub-criteria under four main criteria. The relative advantage criteria of these sub-criteria under the main criteria of innovation is that it is believed to be more than the benefits of innovation. In other words, the more the relative advantage of a technology, the greater the likelihood of adoption. Complexity sub-criteria is the degree of difficulty in understanding how to use the innovation offered. Relevance sub-criteria is the degree to which the compatibility of an innovation is perceived to be consistent with past experiences. Recognition sub-criteria, the introduction of innovations related to Industry 4.0 by the relevant institutions is the status of the enterprise. The intelligibility sub-criteria are the difficulty in adapting Industry 4.0 applications to existing business processes and commercial activities.

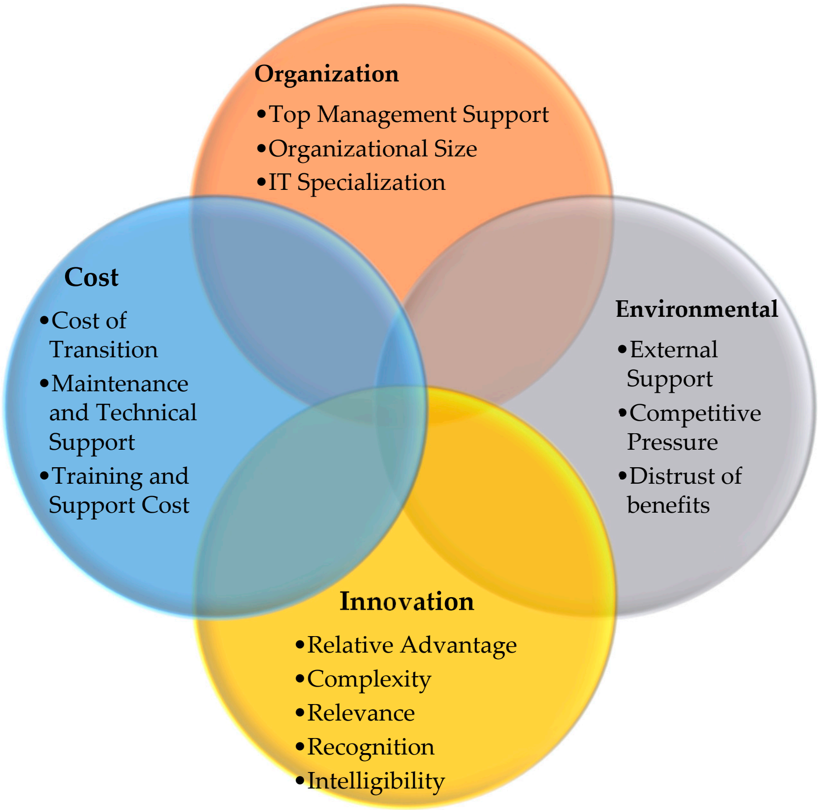

Figure 2. Network structure.

The sub-criteria of top management support is under the main criteria of the organization, the greater the support of senior management to new technologies, the greater the adoption of these innovations. With the support of top management, various studies can be done, and sufficient resources can be allocated for the adoption of new technologies. The organizational size sub-criteria are related to the increase in the acceptance rate of the innovations of the enterprise. It is stated that larger organizations show more flexibility and that innovations can be tried. The sub-criteria of IT (Information Technology) specialization is defined as being aware of new technologies and having knowledge about these technologies.

The sub-criteria of competitive pressure under the environmental main criteria is the competitive pressure to compete with other enterprises in the same market. The external support sub-criteria refers to an external support for the implementation and use of a new system. The sub-criteria of distrust of benefits which is distrust to the benefits it brings is stated as the protectionist response to the unknowns and the lack of confidence in the benefits of these innovations.

The transition cost criteria under the cost criteria is the possible costs of new technologies or systems that need to be integrated with the company for these processes. The sub-criteria of maintenance and technical support cost is the cost of maintenance and maintenance-related technical support to ensure the continuity of new technologies integrated into enterprises. The training and support cost sub-criteria is the training requested and the support cost associated with this training, for the first time the new technologies are integrated into the enterprises.

Step 2. Creation of comparison matrices between the criteria: After the hierarchical structure of the determined criteria was established, the paired comparison matrices were formed in consultation with SME experts and business managers. Table 3 shows the comparison matrix established between the main criteria. For example, a binary comparison matrix is given between the main criteria. Similar comparison matrices were established among other criteria. The experts evaluated the criteria. These factors were evaluated with 15 SME experts and management officers.

Table 3. Comparison matrix between criteria.

Main Criteria	Cost	Organization	Environmental	Innovation
Cost	1	1/2	4	5
Organization	2	1	3	4
Environmental	1/4	1/3	1	4
Innovation	1/5	1/4	1/4	1

Step 3. Calculation of the weight of the criteria: Calculations of the AHP method in the solution process were made by using the comparison matrix in Table 3. The matrix was normalized to determine the significance weights of each criterion. Table 4 shows the normalized matrix. Normalization is done by dividing each column value separately by the respective column. Moving from the normalized matrix; the average of each sequence value is taken. These values are the percentage weights for each criterion. Table 5 shows the importance weights of each of the main criteria and sub-criteria. Binary comparison matrices are created by taking into account the questions in Table A1.

Table 4. Normalized matrix.

Normalized	Innovation	Innovation	Innovation	Innovation
Cost	0.29	0.24	0.48	0.36
Organization	0.58	0.48	0.36	0.29
Environmental	0.07	0.16	0.12	0.29
Innovation	0.06	0.12	0.03	0.07

Table 5. Criteria and sub-criteria weights.

Main Criteria	Main Criteria Weight	Sub-Criteria	Sub-Criteria Weight
Innovation	0.07	Relative Advantage	0.14
		Complexity	0.31
		Relevance	0.06
		Recognition	0.36
		Intelligibility	0.13
Organization	0.43	Top Management Support	0.64
		Organizational size	0.09
		IT Specialization	0.27
Environmental	0.15	External Support	0.27
		Competitive Pressure	0.64
		Distrust of benefits	0.09
Cost	0.35	Cost of Transition	0.1
		Maintenance and Technical Support	0.23
		Training and Support Cost	0.67

Step 4. Checking the consistency ratios of the comparison matrices: The consistency ratio was calculated in order to know the accuracy of the operations performed in the calculation steps of the comparison matrices and the consistency in the comparisons made by the decision makers. According to the implementation steps of the method, the consistency ratio is less than 0.1 and it shows the consistency and consistency of the evaluations. In this study, the consistency ratios in all comparison matrices between main criteria and sub-criteria were calculated as less than 0.1. Table 6 shows the consistency ratios of each binary comparison matrix.

Table 6. The consistency ratios of each binary comparison matrix.

Binary Comparison Matrix	Consistency Ratio
Binary comparison matrix between main criteria	0.099
Binary comparison matrix of sub-criteria under the main criterion of innovation	0.097
Binary comparison matrix of sub-criteria under the main criterion of cost	0.082
Binary comparison matrix of sub-criteria under the main criterion of environmental	0.051
Binary comparison matrix of sub-criteria under the main criterion of organization	0.051

3.2. Application with ANP Method

In this study, it was planned to analyze the difficulties faced by SMEs in Industry 4.0 processes and applications. Considering the interaction between the criteria, it was aimed to determine how the results will change. When determining the criteria, the study of Premkumar and Roberts [45] was used from the literature. In this study, innovation, organization, and environmental main criteria were taken into consideration. In the sub-criteria, relative advantages, complexity, relevance, top management support, organizational size, IT expertise, competitive pressure, and external support sub-criteria were taken into consideration. Cost main criteria, recognition, intelligibility, distrust of benefits, cost of transition, maintenance and technical support, training and support cost sub-criteria were determined according to the opinions of experts. Interviews and interactions between criteria were discussed by the experts. In line with these opinions, the network structure was formed. According to the network structure, the main criteria and sub-criteria were taken into account interactions, feedback and relationships. This network structure is given in Figure 2.

According to this network structure, when the interactions between criteria and sub criteria are considered, the main criteria are in relation with each other. The sub-criterion of top management support under organizational criteria affects all sub-criteria, as it includes information on all innovations and processes related to technology in an organization. All sub-criteria are affected by top management support. In this case the interaction within the criteria itself occurs. In another example of interaction, the cost of transition under the cost criterion, in a way, covers all costs and therefore affects other costs. Other sub-criteria under the cost criterion are affected by the transition cost criterion. All interactions were determined according to the relationship between the criteria. The experts helped to form the network structure by taking these relationships into account. The relationship of the criteria which are effective in this study which includes the analysis of the difficulties experienced in the transition period of the SMEs to the Industry 4.0 are reflected in Figure 2. According to this network structure, binary comparison matrices were formed, and the solution process was continued in the other steps of the ANP method.

Binary comparison matrices were formed by considering the network structure in Figure 2. In the solution process of the ANP method, the Super Decision package program was used. According to this network structure, binary comparison matrices were established, and benchmarks were compared to each other. In this comparison, a scale of 1 to 9 by Saaty was used. Experts made comparisons with the help of this scale. These factors were evaluated with 15 SME experts and management officers. An example comparison matrix is shown in Table 7 prepared using the binary comparison matrix. There are two types of comparisons, one at the main criteria and one at the level of the sub-criteria. In the matrices, first each main group is compared with the control group, then each criterion is compared with the criteria in the control group.

Table 7. Comparisons with respect to "complexity" node in "innovation" cluster.

Intelligibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Recognition
Intelligibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Relevance
Recognition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Relevance

Table 7 shows that there are interactions within the main criteria of innovation. Considering these interactions, similar comparison matrices were established with the help of the package program. The benchmarks were compared.

After all the comparison matrices were created, the eigenvectors of the criteria and the consistency analyzes were made by means of the package program. It is recommended that the consistency ratio of a matrix be equal to or less than 0.10. Consistency rates of all matrices were found to be less than 0.1. After the completion of the binary comparisons, the limit matrix of the model was obtained. Table 8 shows the importance weights obtained as a result of all calculations.

Table 8. Weights from ANP (Analytical Network Processes).

Innovation	0.114	Relative Advantage	0.232
		Complexity	0.291
		Relevance	0.192
		Recognition	0.127
		Intelligibility	0.157
Organization	0.411	Top Management Support	0.440
		Organizational size	0.280
		IT Specialization	0.280
Environmental	0.190	External Support	0.323
		Competitive Pressure	0.461
		Distrust of benefits	0.216
Cost	0.285	Cost of Transition	0.393
		Maintenance and Technical Support	0.282
		Training and Support Cost	0.325

Table 9 shows the comparison of the main criterion weights obtained as a result of AHP and ANP applications.

Table 9. Comparing the main criteria weights according to AHP (analytic hierarchy process) and ANP results.

Criteria \ Weights	AHP Weights	ANP Weights
Innovation	0.06	0.114
Organization	0.43	0.411
Environmental	0.15	0.190
Cost	0.35	0.285

4. Discussion and Conclusions

In this study, the perspectives, approaches, and applications of SMEs against Industry 4.0 were evaluated. The analysis of the criteria that are effective at these stages was done by the AHP and ANP methods. The organizational criteria were 0.43 in the AHP method and 0.41 in the ANP method. The cost criteria were 0.35 in the AHP method and the rate in the ANP method was 0.28. In AHP, the environmental criterion is 0.15 and the innovation criterion is 0.06, whereas in ANP these values are 0.19 and 0.114. However, when the weight of the factors is listed, the first order is the organization, the second order is the cost, the third is the environmental, and the last order is innovation. Considering the weights of factors affecting the Industry 4.0 adaptation, there was no change in rankings. This results in the result of the ANP method being supported by the AHP method.

The fact that firms are not convinced by the Industry 4.0 transition is understood from the fact that the organization and cost criteria have more weight. The high cost of investment based on technology and the neglect of its return are factors that prevent firms from being convinced. Understanding the contribution of the Industry 4.0 transition to competitiveness and the production of financial solutions will make it easier for company officials to make positive decisions.

In the literature, the concept of Industry 4.0 and its necessity, its contribution to continuity in production, the industrial conditions after the emergence, and the state of technology have been examined. The proposed studies for the development of digital networks were examined. In addition, studies on the analysis of the factors in the formation of successful IoT systems and the determination of the best strategies of the Industry 4.0 applications were emphasized. Lee and Runge [46] provide explanatory information on how to adopt information technologies for small businesses. For example, Camisón [47] which in empirical research, noted the contribution and advantages of information technologies to their competitiveness. Raza et al. [48], Bakkari and Khatory [49], Corò et al. [50] focus on the main conditions that are necessary to move to Industry 4.0. The transition of firms to automation processes reduces the dependence on people and reduces the cost and increases the efficiency. However, it can be seen in the literature that it is an undesirable process for enterprises to make use of electronic environment and operations in these environments. Srinivasan et al. [51], Davis and Vladica [52], Khalfan et al. [53] mentioned the lack of interest in electronic commerce and market. Al-Qirim [54], Tan et al. [55] and Ifinedo [56] who conducted research on the adoption of e-commerce communication and application technologies, turned the focus to SMEs. In this study, the main factors for the adaptation of SMEs to Industry 4.0 were determined by the AHP and ANP methods. AHP and ANP methods were used in the study. These methods are useful tools to obtain effective results in the problem we are dealing with. In this study, the literature was reviewed. At the same time, SME experts and SMEs in the manufacturing sector were interviewed. As a result, a questionnaire was applied to determine the main criteria and sub-criteria related to the transition to Industry 4.0. Based on the information received from these experts, important factors were identified in the transition to Industry 4.0 for SMEs. The limit of this study is the small number of experts whose problems are evaluated. Increasing the number of experts, and even evaluating these criteria with business owners will further improve the results of the study. At the same time, a general analysis of the study can be seen as the boundaries of the study because some of the results can be different for some businesses or there may be special restrictions/exceptions for each business. In addition, the adoption behavior of SMEs is slightly different compared to enterprises with more opportunities and resources. At this point, it is necessary to analyze the impulses affecting the adoption processes discussed in this study. SMEs are still struggling to integrate information technologies, the internet of objects, in short, the concept of Industry 4.0. Even if the business owners realize the importance of the results of the study, they ignore this awareness and continue their traditional processes. At this point, the inadequacy of the practices regarding the awareness of SMEs is among the limits of the study. At the same time, these factors may have uncertainty levels. The fact that these uncertainty levels are not considered in the study limits the practices of the study.

When all the works mentioned have been examined, it can be seen that all enterprises need many technological developments and innovations brought by the concept of Industry 4.0. In terms of the importance of the concepts and the benefits it will bring, it is necessary to follow these technological processes in order to have competitive power in the market. Small and medium-sized enterprises should analyze the main reasons for the difficulties experienced when adopting these processes. Then they should complete their transition to these processes as soon as possible with well-made plans and well-structured strategies.

This study is one of the first studies in the literature to analyze the challenges of SMEs in the transition to Industry 4.0 and to evaluate the factors that are effective. According to similar studies in the literature, Van de Vrande et al. [57] analyzed whether or not innovation practices are implemented by SMEs. Faller and Feldmüller [58] focused on the necessity of training the applications of Industry 4.0 scenarios that allow for the adaptation to SMEs. Sommer [59] analyzed the awareness and capabilities of enterprises by looking at Industry 4.0 in terms of SMEs. Caldeira and Ward [60], Lee [61], Julien [62], and Liere-Netheler [63] introduced a conceptual perspective on the factors affecting the adoption and use of information systems and technologies by SMEs. In this study, the difficulties in these adoption processes were taken into consideration and their reasons were approached analytically. In addition, in this study, researchers and enterprises can evaluate the factors that are effective in these processes and organize their strategic goals. Considering the mentioned limits of the study, different studies or additions may be made in order to improve the study. For example, in future studies, decision-making situations can be analyzed in fuzzy environments. Based on these factors, internal evaluations can be carried out in enterprises. Statistical analysis can be done by increasing the number of evaluators.

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Appendix A. Questionnaire Table for Experts (Important Factors for Transition to SMEs Industry 4.0 Technologies)

Table A1. Questionnaire table for experts.

No	Questions	I Strongly Disagree	I Don't Agree	Undecided	I Agree	Absolutely I Agree
	Innovation/Organizational/Environmental/Cost					
1	Innovations should be made in the Industry 4.0 transition.					
2	In Industry 4.0 transition, technologies enable businesses to adapt to both business processes and commercial activities.					
3	The benefit from the innovation offered for Industry 4.0 is expected.					
4	In order to keep our products and brands in the market and to compete with their competitors, we must pass to Industry 4.0 technologies.					
5	The compatibility of the Industry 4.0 innovation is consistent with past experiences.					
6	It is difficult to understand the innovation offered in Industry 4.0.					
7	Some of our potential customers ask us to switch to Industry 4.0 technologies to do business with our business.					
8	There is no information about the introduction of innovations related to Industry 4.0 by the relevant institutions.					
9	Industry 4.0 applications are difficult to adapt to existing business processes and commercial activities.					
10	Transition to Industry 4.0 Technologies will increase the operational speed and flexibility of our business.					
11	The greater the relative advantage of technology, the greater the likelihood of adoption.					
12	Our business management is willing to adopt new technologies and will accelerate the adoption of innovations.					
13	We can get training and consultancy about Industry 4.0 technologies.					
14	The size of the enterprise is related to the increase of the acceptance rate of innovation.					
15	Information technology expertise for Industry 4.0 is very important.					

Table A1. *Cont.*

No	Questions	I Strongly Disagree	I Don't Agree	Undecided	I Agree	Absolutely I Agree
16	Machine and technology infrastructure that we use in order to transition to Industry 4.0 technologies is required.					
17	The transition to Industry 4.0 should be done to reach the level of competitiveness with other businesses in the same market.					
18	External support should be received in Industry 4.0.					
19	The transition to Industry 4.0 will have a positive effect on SMEs in strategic planning.					
20	Industry 4.0 transition costs correspond to a significant amount for SMEs.					
21	Maintenance and technical support in the Industry 4.0 transition is a requirement for SMEs. Maintenance and support costs will increase.					
22	Training and support in the Industry 4.0 transition is a requirement for SMEs. Training and support costs will increase.					

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