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Evaluation of Industry 4.0 Transformation Barriers for SMEs in Turkey

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Türkiye'deki KOBİ'lerin Endüstri 4.0 Dönüşüm Engellerinin Değerlendirilmesi	Evaluation of Industry 4.0 Transformation Barriers for SMEs in Turkey
Öz	**Abstract**
Endüstri 4.0 ile ilgili gelişmeler birçok ülke için önemli bir konu haline gelmiştir. Ekonominin bel kemiği olarak kabul edilen istihdam ve girişimcilik açısından kilit bir noktada olan KOBİ'ler, Endüstri 4.0'ın uygulanması konusunda önemli bir yere sahiptirler. Türkiye'nin mevcut dijital dönüşüm seviyesi dikkate alındığında KOBİ lerin Endüstri 4.0 çalışmalarında engellerin belirlenmesi ve önceliklendirilmesi KOBİ lerle ilgili geliştirilecek politikalara yön verecektir. Bu çalışmada Türkiye'de KOBİ lerin Endüstri 4.0 dönüşüm çalışmalarında karşılaştıkları engeller konusundaki literatür çalışmaları değerlendirlmiş, öne çıkan engeller belirlenmiş, engellere ait öncelikler uzman görüşlerinden yararlanılarak AHP yöntemiyle analiz edilmiştir.	Industry 4.0 advancements have become substantial issues for many countries. SMEs are considered the backbone of the economy and have a significant place in terms of employment and entrepreneurship and have great significance regarding the application of Industry 4.0 advancements. When the current digital transformation level of Turkey is considered; identification and prioritization of the barriers of SMEs will guide the policies to be developed. In this study, the literature on the barriers faced by Turkish SMEs in their Industry 4.0 transformation efforts is evaluated, prominent barriers are prioritized based on the opinions of experts using the AHP method.
Anahtar Kelimeler: Endüstri 4.0 Dönüşüm Engelleri, Endüstri 4.0'ın Benimsenmesi, Dijital Dönüşüm, Türkiye, KOBİ'ler	**Keywords:** Industry 4.0 Transformation Barriers, Industry 4.0 Adoption, Digital Transformation, Turkey, SMEs
JEL Kodları: D70, M10, L20	**JEL Codes:** D70, M10, L20

Araştırma ve Yayın Etiği Beyanı	Bu çalışma bilimsel araştırma ve yayın etiği kurallarına uygun olarak hazırlanmıştır.
Yazarların Makaleye Olan Katkıları	Yazar 1'in makaleye katkısı %50, Yazar 2'nin makaleye katkısı %50'dir.
Çıkar Beyanı	Yazarlar açısından ya da üçüncü taraflar açısından çalışmadan kaynaklı çıkar çatışması bulunmamaktadır.

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1. Introduction

Industry 4.0 is a term for the ongoing digitization and automation in society (Vrchota et al., 2019). The term represents the new industrial revolution, and it aims to insert the area of data science into the industry in order to generate smart factories to enhance production (Bayram and İnce, 2018). However, Industry 4.0 does not have a clear definition. The definition of the term is still considered contested, which poses "serious limitations to theory building and research comparability" (Culot et al., 2020). In today's business, the potential behind the Industry 4.0 concept is the digitalization of value chains and product and service offerings of the companies (Sarvari et al., 2018). Early adopters of Industry 4.0 have seized the opportunities, developed a competitive advantage, and secured market share in the first wave of Industry 4.0. The second wave increasingly involves SMEs, many of which are still in the cost-benefit analysis phase (Jovanovski et al., 2019). Companies are now growing rapidly to integrate the concepts of Industry 4.0. However, with information technology and operational technology combined, new challenges have emerged. Horváth and Szabó, (2019) state that only several empirical studies have been found in the literature regarding Industry 4.0 as these studies on barriers of Industry 4.0 generally focus on only one specific aspect and they are very limited since Industry 4.0 is considered a complex phenomenon.

Turkey is in the process of grasping Industry 4.0. As a government policy, it is planned "Digital Transformation Centers" to be opened and consultants to be trained to support the transformation of SMEs in Turkey (Sanayi ve Teknoloji Bakanlığı, 2017). However, research was conducted on the evaluation of SMEs regarding Industry 4.0 in Eskişehir, Turkey (Kagnicioglu and Ozdemir, 2017); and the study found that there is only a mediocre awareness level in SMEs. Turkish SMEs need more information about the adoption of Industry 4.0 (Gergin et al., 2019). In parallel to this, it has been found that leading enterprises in Turkey cannot focus on core technologies of digital transformation due to their focus on investment costs (Nuroğlu and Nuroğlu, 2018). In Turkey, SMEs represent around %99 of the area of entrepreneurship, which makes them crucial regarding the development and sustainability of the industry while having an important function in terms of the development of the economy (Sevinç et al., 2018). Turkey has taken some steps towards increasing innovation and digitalization of SMEs with development plans, incentives, and making loans available to SMEs. Turkish Government supports SMEs through KOSGEB (Small and Medium Enterprises Development Organization) and TUBİTAK (Scientific and Technological Research Council of Turkey). The main goal for the support is to ensure companies have new networks, systems, applications, and devices (Cagle, 2020).

Considering Turkey is theoretically five years behind on Germany in terms of Industry 4.0 (Nuroğlu and Nuroğlu, 2018), Turkish SMEs do not have adequate information about Industry 4.0 (Kagnicioglu and Ozdemir, 2017); and the importance of their unique position in this industrial revolution, barriers of transformation of SMEs should be evaluated and prioritized. In this study, barriers are identified from the literature, and experts from Turkey were asked to prioritize them with pairwise comparisons. Analytic Hierarchy Process (AHP) method, which is a multi-criteria decision making (MCDM) technique is used for prioritization of the barriers. This study contributes to the literature by identifying, evaluating, and prioritizing the barriers for SMEs in Turkey.

2. Industry 4.0 and SMEs

Due to the latest developments, companies are faced with the pressure to embrace digitalization strategies, adopt new technologies which Industry 4.0 brings, and define the role of workers in this industrial revolution (Pessl et al., 2017). Hence, the changes that occurred in both economic and social aspects resulted in new programs and actions that promote and support the digitization of the industry (Türkeș et al., 2019).

According to World Trade Organization, SMEs represent over 90% of the business population, over 60% of the employment, and 55% GDP in developed economies (World Trade Organization, 2016). Industry 4.0 brings the potential to provide better information, which brings better planning processes (Moeuf et al., 2018). Vrchota et al. (2019) state that the Industry 4.0 concept is no longer just a topic for only large companies. As SMEs are fundamentally different compared to large enterprises, they need different strategies to implement Industry 4.0 (Müller et al., 2017). Furthermore, they have different characteristics. One of the characteristics that stand out among the differences is flexibility. SMEs have high flexibility when it comes to customer requirements while large enterprises have employees dealing with specific areas, which is usually not true for SMEs (Vrchota et al., 2019). Industry 4.0 seems attractive to SMEs since SMEs often have business strategies on flexibility. The flexibility of SMEs means that they can easily adapt to changes, but the insufficiency of SMEs in terms of finance and management weakens their competitiveness (Sabuncu, 2014). In the literature, the necessity is stressed to evaluate the financing method and the suitability of the investment, and the economic outcome if the investment is decided in the new technologies (Huh and Lee, 2018). A high-tech strategy is considered as an important key element which industry 4.0 is built on and innovations have underpinned its development (Türkeș et al., 2019). SMEs which are users of Industry 4.0 are mainly driven by operational opportunities while large enterprises that are providers of Industry 4.0, particularly driven by strategic benefits (Müller et al., 2018). The flexible organizational structures of SMEs offer advantages such as rapid adaptation to innovations in technology, being able to offer more diverse products and obtaining more output with less input, as well as the ability to adapt to changes in the markets simultaneously (Türkoğlu and Çelikkaya, 2011). In addition, it is important for SMEs to provide employment opportunities to a large number of employees; entrepreneurs who do not work for an employer but start their own enterprise are also of great importance from an economic perspective (Taş, 2018).

"Industry 4.0 reduces non-value-added data manipulation, improves OEM/SME based supply chain communications, enhances SME supply chain business performance, addresses interoperability concerns across both technical and business domains of the digital enterprise, opens new manufacturing technological career opportunities, and integrates the human in the digital world to enhance decision making." (Önday, 2018). Through Industry 4.0 implementation; new business models & value creation networks will lead to a new way of communication in the supply chain network and smarter production processes could lead to higher product quality in SMEs. Although, it is also stated that these technologies are in different stages in terms of advancement; thereby, possible positive effects are currently unclear to measure (Jovanovski et al., 2019).

3. Industry 4.0 Transformation Barriers

Despite Industry 4.0 bringing both changes and opportunities, it also brings challenges that can be considered as threatening to businesses (Doğru and Meçik, 2018). A study conducted by Sevinç et al. (2018) has analysed propulsion forces of Industry 4.0 that are adopted in SMEs. A total of four main criteria were determined which are the organization, environmental, innovation, and financial. This study is one of the first studies to analyse barriers of SMEs in their progress to Industry 4.0. However, the criteria considered were based on the study of Premkumar and Roberts (1999) which only examined innovation, organizational and environmental characteristics in small businesses. Another study conducted by Jovanovski et al. (2019) examined the challenges of SMEs in terms of Industry 4.0 implementation. However, the study lacks any form of prioritisation of those challenges. A study by Raj et al. (2019) identified barriers to Industry 4.0 adoption in the manufacturing sector in India and France. The study found out the barriers are different in developing and developed countries because of the diverse policies of Industry 4.0. The impact of Industry 4.0 can differ between industries and even countries (Smit et al., 2016). Nevertheless, the study does not specifically address barriers to SMEs; instead, it is focusing on the manufacturing industry only. According to Stentoft et al. (2019) Industry 4.0 barriers decrease the readiness of SMEs and make them less ready for Industry 4.0 while it does not affect their utilization of the technologies.

Schumacher et al. (2016) examined the problems companies face during Industry 4.0 implementation that is stated as the inadequate strategic guidance and perception of Industry 4.0 along with the uncertainty of outcomes of Industry 4.0 projects and failure of assessing the company in terms of Industry 4.0 capability. According to Stentoft et al. (2019) Industry 4.0 barriers, decrease the readiness of SMEs to Industry 4.0 while no relationship has been found between barriers and practicing Industry 4.0 regarding SMEs, which means barriers have no direct influence on the use of Industry 4.0 technologies by SMEs. It is also observed that despite the new emerging technologies, SME’s either do not benefit or benefit insufficiently from these technologies (Moeuf et al., 2018). Smit et al. (2016) found that there are three key aspects of Industry 4.0, which are technological, social, and change in the business paradigm. Regarding technological change, many businesses recognize the challenges of Industry 4.0 while far fewer businesses; especially SMEs are not prepared for it. The impact of the new industrial revolution on the industry is likely to result in new business models emerging that have a huge potential to reshape the entire life cycle of the products, improve business processes and enhance the competitiveness of the companies (Pereira and Romero, 2017). A roadmap support business to acknowledge moves, what decisions need to be made, when and who needs to make those decisions (Sarvari et al., 2018). When the literature on Industry 4.0 transformation barriers is examined, it is seen that the main problems that stand out are shaped around 9 dimensions. Those dimensions are as follows: Limited Financial Resources (1), Lack of Digital Strategy (2), Lack of Knowledge and Awareness about Industry 4.0 (3), Lack of Qualified Workforce and Continuous Training of Workforce (4), Lack of Standards and Legislation (5), Organizational Resistance (6), Operational Use of Digital Technologies and Lack of Operational Processes (7), IT Security Issues (8), Reliability and Stability of IT Systems (9). These dimensions will be used to determine the dimensions to be used in the AHP analysis.

3.1. Limited Financial Resources

Large investments in new technologies will be required for the transformation to Industry 4.0 as "one of the main factors influencing the implementation of Industry 4.0 is the initial investment associated with the acquisition of new technologies" (Sung, 2018; Vrchota et al., 2019). R&D activities and the cost of essential technologies is a barrier for many SMEs (Jovanovski et al., 2019). Having limited resources, investing in new technologies and ERP systems also constitutes a barrier for SMEs (Grandhi and Chugh, 2012; Haddara and Zach, 2012). Enterprises that are not yet prepared for Industry 4.0 will face extreme changes and high-cost investment needs (Trstenjak and Cosic, 2017). IT security budgets are expected to increase due to new platforms and operating systems (Ervural and Ervural, 2018). Furthermore, it should be noted that in the matter of investment capacity and operational performance, SMEs are in a weak position compared to large enterprises. In addition, the short-term strategies of SMEs do not constitute an advantageous situation for long-term investments (Moeuf et al., 2018).

3.2. Lack of Digital Strategy

According to Ghobakhloo (2018) organizations that are mature enough to embrace this revolution have developed a strategy to transition to Industry 4.0. With Industry 4.0 new business models have emerged and SMEs describe their business models are insufficient to create value from data (Birkel et al., 2019). In the literature, the lack of digital strategy is identified as an obstacle for the Industry 4.0 implementation of SMEs. (Jovanovski et al., 2019; Nagy et al., 2018). TÜBİSAD (2020) claims Turkey's digitalization strategy needs a better design, as Turkey needs a high-level roadmap and strategy that can be adopted; the digital transformation strategy must be holistic, and the work carried out by different institutions in different fields must be coordinated. The outcome of Industry 4.0 relies on both the creation implementation of a corporate digital strategy (Nagy et al., 2018). In addition, Horváth and Szabó (2019) consider lack of conscious planning as a barrier which includes defining goals, steps, and needed resources.

3.3. Knowledge and Awareness of Industry 4.0

Turkish industry sits between the 2nd and 3rd industrial revolution while the Industry 4.0 awareness amongst enterprises is identified as low (Nuijens, 2017). Çakmak (2018) found that employees in Turkey are not aware of Industry 4.0. As Turkey does not want to fall behind in this industrial revolution, SMEs that are already analyzing their opportunities are positioning themselves based on the new trends that have already overcome the Awareness of the Industry 4.0 barrier (Jovanovski et al., 2019). Stentoft et al. (2019) provided empirical evidence on perceived drivers for Industry 4.0 leading to industry 4.0 readiness, which causes a greater degree of Industry 4.0 practice. In addition, in terms of social change, there is a "lack of awareness of Industry 4.0 outside the group of stakeholders" (Smit et al., 2016).

3.4 Lack of Qualified Workforce and Continuous Training of Workforce

It is expected that Industry 4.0 will have a serious impact on employment (Cimini et al., 2019). It is foreseen that Industry 4.0 will shorten working hours and demand good education/background and new competencies from workers (Taş, 2018). At this point, education policy comes to the forefront and a special effort is needed for education in Industry 4.0 (Nuroğlu, 2018). Sivathanu and Pillai, (2018) stated that talent development is crucial in Industry 4.0 and artificial intelligence can be used to identify knowledge gaps for workers as the skill demands in the market constructs the basis. It is believed that training and education will be crucial in the transformation process (Çakmak, 2018).

Cevik Onar et al. (2018) investigated four main groups regarding the content of the Industry 4.0 education which are data and computing technologies, value-added automated operation, domain knowledge, and innovation and entrepreneurship. Industry 4.0 requires more than hard skills but in today's economy, job-related qualifications are more prominent (Prifti et al., 2017). However new ways of work are needed for the employees although these new ways may have unexpected impacts on the employees (Smit et al., 2016). Ludwig et al. (2018) stated that increasing technological innovation would demand more effort on the part of workers in the form of advanced training. Furthermore, lifelong learning is becoming progressively significant. This allows businesses to make suitable deals and provide educational breaks. Milanesi (2020) argued that the need to acquire new digital skills has accelerated during the COVID-19 pandemic. Job-related training opportunities are gaining popularity in the sense of Industry 4.0. One of the substantial concerns about Industry 4.0 is that robots/machines will replace workers in employment, resulting in massive unemployment, as low-skilled jobs will decline (Vrchota et al., 2019). Although such fears have been experienced at the beginning of the past industrial revolutions, unemployment is not expected to be a problem in the long term as it will also create new jobs.

3.5 Lack of Standards and Legislation

The absence of uniform principles and guidelines for the implementation of IT systems and data and machinery within the organization is another challenge since "an international standard has not yet been implemented" (Jovanovski et al., 2019). According to Igor et al. (2016), communication between devices is a crucial element for the basis of enterprises in the Industry 4.0 standard. Birkel et al. (2019) claim there is another risk and challenge for enterprises, which is the ERP systems since ERP systems have potential guidelines that must be consolidated and made compatible. Furthermore, the authors state that "clear interfaces must be drawn between systems and standards must be established" as technical integration into the operational processes requires a system that fits the best. In addition to the lack of Industry 4.0 standards, there is no legislation and proper working measures (Jovanovski et al., 2019). New regulations will be required on employee rights due to changes in work. Some white-collar workers work from home while the future of the blue-collar workers is not clear and no action has yet been taken (Çakmak, 2018).

3.6 Organizational Resistance

In the literature, general reluctance to change by stakeholders is considered a barrier (Sung, 2018), and resistance to change is identified as a considerable factor for change failure (Goksoy, 2020). As many businesses hesitate or fail to act or react to Industry 4.0, Vey et al. (2017) claim the reasons for that are sophisticated and multifaceted as sometimes they are related to corporate culture. Birkel et al. (2019) examined that the resistance may come from older employees, and this becomes a risk if older employees and senior managers do not back this transformation. Nevertheless, their knowledge and experience may be vital in the transformation of the enterprise. Furthermore, authors find the lack of openness may cause "a paralysis" as organizations miss vital developments if there is resistance.

3.7 Operational Use of Digital Technologies and Lack of Operational Processes

According to Marcon et al. (2019), the lack of operational processes is a barrier since operational processes support digitalization and the time needed for the implementation of digital technologies. Furthermore, Stentoft et al. (2019) claim that Industry 4.0 readiness includes the drive to modify and transform the current processes and willingness to take risks with the technologies. Re-engineering work methods and processes are a challenge for leaders (Gagnon, 2018). According to Igor et al. (2016), leaders in automation have testing facilities for Industry 4.0 technologies, where they can test deployment and development of Industry 4.0. The benefits of Industry 4.0 can offer outputs for many areas, especially in technology management since benefits are prominent in the automation of processes (Fettermann et al., 2018). Marcon et al. (2019) examined barriers for the digitalization of servitization and stated "usage" as a barrier. Since there are scholars (Frank et al., 2019) who address servitization and industry 4.0 as complementary and related concepts, the operational use of digital technologies is considered a barrier in this study. "Usage includes compatibility with current technologies, difficulty in using digital technologies and how mobile and cloud-based digital technologies are" (Marcon et al., 2019). Fettermann et al. (2018) claim that many industries going through an extensive transformation as a reaction to Industry 4.0; the implementation of automation improves the quality of the products while shaping the manufacturing processes to be more effective.

3.8 IT Security Issues

Information technology has become important as finance or human resources in today's business (Günebakan, 2016). Initially, cyber security was a problem for IT but nowadays it has become an agenda for all senior executives (Ervural and Ervural, 2018). In the literature, it has been stated that security-related issues will be a challenge in Industry 4.0 (Sung, 2018). Depending on application areas of Industry 4.0, some security challenges are evident such as misuse of personal information. In contrast to this, there are also specific challenges depending on the structure of the industry (Ervural and Ervural, 2018).

Internet of Things constitutes a significant barrier as many smart devices transmit a huge amount of data without encryption, which causes risks of privacy (Karacay and Aydın, 2018). Privacy is not only a matter for the customer but also the manufacturer (Sung, 2018). Industry 4.0 technologies create delicate data on a huge scale, which includes product information, delivery details, sensor data, test results, and so on. Thus, Ludwig et al. (2018) stress the question "if the data measured by sensors owned by the manufacturer, by the manufacturing company, or by the customer who ultimately pays for the production process".

3.9 Reliability and Stability of IT Systems

Igor et al. (2016) claim insufficient flexibility in the level of automation technology causes difficulties to implementation of Industry 4.0. Hermann et al. (2016) examined the "Interconnection" concept as an Industry 4.0 design principle and stated, wireless communication technologies have an important role in terms of expanding interaction as these technologies allow for ever-present internet access. In parallel to this, Sung (2018) identified "reliability and stability needed for a critical machine to machine communication" since a decent latency is needed for the machines while satisfying the need to maintain the integrity of the production process to evade IT problems as those issues would cause production interruptions which will have a costly impact on the organization. Especially in automation, timing is critical and timing requirements must be satisfied (Igor et al., 2016). Furthermore, Horváth and Szabó (2019) identified technological integration as a barrier. A full integration of IT, which makes possible the external information exchange, is rare in SMEs (Schröder, 2017).

4. Methodology

Analytical Hierarchy Process (AHP) method is applied to prioritize the barriers. AHP was selected due to its simplicity and straightforward analysis features. "The Analytical Hierarchy Process (AHP) is a general theory of measurement. It is used to derive ratio scales from both discrete and continuous paired comparisons. These comparisons reflect the relative strength of preferences and feelings" (Saaty, 1987). AHP was one of the first Multi-Criteria Decision-Making methods based on hierarchies for quantitative decision-making (Czekster et al., 2019). The 8 decision-makers who participated in this study are selected based on their relevance to the subject. The decision-makers are experts in their fields. Some of the experts are academics while some are executives and IT consultants. In addition, all respondents have degrees in relevant fields such as Business Management, Computer Science, and Industrial Engineering which are considered relevant fields to Industry 4.0 in the literature (Lasi et al., 2014).

Analytical Hierarchy Process always starts with a goal statement then builds a decision tree as "it provides an organized description of hierarchical interaction or connection among the impacts and criteria" (Reza et al., 2011).

The application of AHP is divided into 5 steps. All calculations are made in Microsoft Excel 2019.

Defined barriers are shown in Table 1. The main goal is indicated in Table 1 and the criteria that contribute to the goal are also listed (Singer and Özşahin, 2018). In AHP, the goal statement is at the highest level while criteria are listed at the lower levels.

Table 1: Dimensions of Industry 4.0 Transformation Barriers of SMEs

Barrier	Source
B1-Limited Financial Resources	(Jovanovski et al. 2019; Sarvari et al. 2018; Stentoft et al. 2019; Sung 2018)
B2-Lack of Digital Strategy	Jovanovski et al. 2019)
B3-Lack of Knowledge and Awareness about Industry 4.0	(Sarvari et al. 2018; Schumacher, Erol, and Sihn 2016; Stentoft et al. 2019; Türkeş et al. 2019)
B4- Lack of Qualified Workforce and Continuous Training of Workforce	(Fettermann et al. 2018; Jovanovski et al. 2019; Sarvari et al. 2018; Stentoft et al. 2019; Sung 2018; Türkeş et al. 2019)
B5-Lack of Standards and Legislation	(Jovanovski et al. 2019; Stentoft et al. 2019)
B6-Organizational Resistance	(Raj et al. 2019)
B7-Operational Use of Digital Technologies and Lack of Operational Processes	(Fettermann et al. 2018; Marcon et al. 2019)
B8-IT Security Issues	(Jovanovski et al. 2019; Ludwig et al. 2018; Stentoft et al. 2019)
B9-Reliability and Stability of IT Systems	(Sung 2018)

The goal is defined as: "Prioritization of the Barriers of SMEs in the Industry 4.0 Transformation."

The second step consists of a comparison of criteria. Normally, pairwise comparisons are established on the nine-point scale in the AHP method. The AHP comparison scale is shown in Table 2, which is based on Saaty's comparison scale (Saaty, 1987, 2008). However, intermediate values between two adjacent judgements are removed to make the respondent decision-making less complex as shown in Table 3. The aim is to find out the importance of the elements.

Table 2: AHP Importance Scale

Intensity of Importance	Definition
1	Equal Importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

(Saaty, 1987, 2008; Wu et al., 2010).

Table 3: AHP Input Example

A	9	7	5	3	1	3	5	7	9	B
Limited Financial Resources								X		Lack of Digital Strategy
Limited Financial Resources			X							Lack of Standards and Legislation

Each element ($a$ij) in the pairwise comparison matrix symbolizes the degree of inclination of the *i*th criterion over the *j*th criterion. After this, the overall decision-maker judgements are determined by using the geometric mean formula given in Equation 1 (Motaki and Kamach, 2017).

$$a_{ij} = \sqrt[n]{a_{ij1} \times a_{ij2} \times \dots \times a_{ijn}} \qquad (1)$$

Pairwise comparisons are essential in the AHP method (Saaty, 1987). Decision-makers indicate for each pair of factors which factor is the most important one. Afterward, decision-makers indicate "to what extent a factor is more important than another in qualitative terms." "The pairwise comparison method converts these comparisons of all pairs of factors to quantitative weights for all factors" (Spatial, 2021).

C1, C2, C3, C4…, Cn are the set of criteria (barrier) and *aij* symbolizes a quantified judgment on a pair of criteria Ci and Cj. The scale for symbolizing the quantified judgment can be the numerical value from 1 to 9, as shown in Table 2 and Table 3, for particular importance levels.

The pairwise comparison matrix is built according to the following rule (Motaki and Kamach, 2017).

$$a_{ij} > 0, \quad a_{ji} = \frac{1}{a_{ij}}, \quad a_{ii} = 1 \qquad (2)$$

The consolidated pairwise comparison matrix is presented below.

Table 4: Pairwise Comparison Matrix

Criteria	B1	B2	B3	B4	B5	B6	B7	B8	B9
B1	1.00	0.69	0.68	1.45	2.28	1.17	0.35	1.73	1.46
B2	1.45	1.00	1.33	3.04	2.56	2.16	0.50	1.10	0.61
B3	1.46	0.75	1.00	2.07	3.71	2.85	1.28	2.35	1.15
B4	0.69	0.33	0.48	1.00	2.14	1.51	0.68	0.68	1.24
B5	0.44	0.39	0.27	0.47	1.00	0.91	0.45	1.28	0.66
B6	0.85	0.46	0.35	0.66	1.10	1.00	0.47	1.17	1.36
B7	2.82	1.99	0.78	1.46	2.23	2.14	1.00	3.71	1.79
B8	0.58	0.91	0.42	1.46	0.78	0.85	0.27	1.00	0.58
B9	0.68	1.63	0.87	0.81	1.53	0.74	0.56	1.73	1.00
SUM	9.97	8.15	6.20	12.42	17.34	13.33	5.56	14.77	9.84

Wu et al. (2010) examined that to determine the priority and rank for each criterion in terms of its percentage there are a set of steps that must be followed:

(1) Sum the values in each column

(2) Division of each element in the matrix by its column total (normalized pairwise comparison matrix)

(3) Calculation of average elements in each row of the matrix

Table 5: Normalized Matrix

Criteria	B1	B2	B3	B4	B5	B6	B7	B8	B9	SUM	Weight
B1	0.10	0.08	0.11	0.12	0.13	0.09	0.06	0.12	0.15	0.96	10.7%
B2	0.15	0.12	0.21	0.24	0.15	0.16	0.09	0.07	0.06	1.26	14.0%
B3	0.15	0.09	0.16	0.17	0.21	0.21	0.23	0.16	0.12	1.50	16.7%
B4	0.07	0.04	0.08	0.08	0.12	0.11	0.12	0.05	0.13	0.80	8.9%
B5	0.04	0.05	0.04	0.04	0.06	0.07	0.08	0.09	0.07	0.53	5.9%
B6	0.09	0.06	0.06	0.05	0.06	0.08	0.08	0.08	0.14	0.9	7.7%
B7	0.28	0.24	0.13	0.12	0.13	0.16	0.18	0.25	0.18	1.67	18.6%
B8	0.06	0.11	0.07	0.12	0.05	0.06	0.05	0.07	0.06	0.64	7.1%
B9	0.07	0.20	0.14	0.07	0.09	0.06	0.10	0.12	0.10	0.94	10.4%

As a result, the weight represents the priorities of the criteria.

The evaluation requires a certain level of matrix consistency. This can be achieved by applying the consistency index (CI) as follows: Firstly, the λmax (the highest eigenvalue of the matrix) is necessary to be determined. λmax is obtained by adding the column vector corresponding to the multiplication of the original comparison matrix with the column vector of relative weights (Romero-Gelvez et al., 2019).

$$\lambda max = \sum_{i}^{n} Aw \qquad (3)$$

Secondly, the consistency index CI is calculated by the following formula (Motaki and Kamach, 2017):

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \qquad (4)$$

(where n is the number of criteria).

The random index (RI) is the average CI value of comparison matrices. Following table is given for RI (Saaty, 1987).

Table 6: Random Index Table

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Since n=9, the RI value is 1.45.

"Each criterion is quantified by finding the value of maximized eigenvalue, consistency index (CI), and consistency ratio (CR). The CR index is used in order to maintain consistency in the decision making of the respondents" (Singer and Özşahin, 2018) Formula is as follows:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RC}} \qquad (5)$$

The consistency index (CI) evaluates the rate of logical consistency among pairwise comparisons. Shinohara and Osawa (2007) examined that when CI= 0.0 logical inconsistency does not exist, and the judgement is considered 100% consistent. Thus, it should be noted that the more the consistency index value increases the rate of logical inconsistency among pairwise comparison judgements also increase.

The Consistency Ratio (CR) is found at 4%. According to Saaty (1980), the value of the Consistency Ratio should not exceed 10%. Since the value is less than 10% the result is consistent and acceptable.

5. Findings and Discussion

Weights of barriers are shown in Table 7.

Table 7: Weights of Criteria

Barrier	Barrier Weight	Barrier Weight %
B1-Limited Financial Resources	0.107	10.7%
B2-Lack of Digital Strategy	0.140	14.0%
B3-Lack of Knowledge and Awareness about Industry 4.0	0.167	16.7%
B4- Lack of Qualified Workforce and Continuous Training of Workforce	0.089	8.9%
B5-Lack of Standards and Legislation	0.059	5.9%
B6-Organizational Resistance	0.077	7.7%
B7- Operational Use of Digital Technologies and Lack of Operational Processes	0.186	18.6%
B8-IT Security Issues	0.071	7.1%
B9-Reliability and Stability of IT Systems	0.104	10.4%

Findings show that "Operational Use of Digital Technologies and Lack of Operational Processes" has the highest weight. Based on the literature (Fettermann et al., 2018) the adoption of Industry 4.0 technologies can change companies fundamentally while these technologies are also enablers of strategies for operations management. Along with the operations barrier, "*Lack of Knowledge and Awareness about Industry 4.0"* has a high weight as a barrier. According to Fettermann et al. (2018) management and control of integrated operations in Industry 4.0 demand skilled employees, which is related to the Human Resources as a barrier. Furthermore, to take advantage of digital technologies for the manufacturing processes "know-how" is necessary. Transition to Industry 4.0 may require a full revision to the company's operations and production processes but the actual employees have significant benefits and training them for the necessary skills is crucial (Ghobakhloo, 2018). Although, how employees make sense of newly attained know-how and adopt it to enhance decision-making efficiency is what distinguishes digital transformation from other fields of study, such as business process reengineering (Schallmo et al., 2017). In contrast to the literature, the experts have considered the *Lack of Standards and Legislation* a less important barrier in this study. Igor et al. (2016) claim that the leaders of Industry 4.0 are working on the implementation of standards which is due to the lack of processes. Similarly, a research conducted by TÜBİSAD (2020) found that current regulations of ICT in Turkey do not respond to the need.

Lack of Digital Strategy is considered one of the important barriers. Gartner (2018) states that the "strategic innovation and technology roadmap is like a GPS for the organization's digital strategy, although the "exact route can change along the way". It is recommended that SMEs in Turkey need collaborations to adopt Industry 4.0 technologies which require medium and long-term digital strategies (Kagnicioglu and Ozdemir, 2017). According to Ghobakhloo (2018), the essentials for transformation to Industry 4.0 is the reinforcement of a strategic roadmap that identifies and plans every step. This strategic roadmap should include a timeline, the expense, and benefits regarding each step. In parallel to this, Safar et al. (2018) underline the importance of a business model for existing or new SMEs in the Industry 4.0 environment.

Sustainable and new business models must ensure mutual business benefits among all stakeholders in the value chain while being clearer and cooperative compared to existing ones. In addition, business models must enable some key areas such as innovation and product development (Prause, 2015). Based on the success cases, Fettermann et al. (2018) observed that despite the lack of roadmap implementation, the cases underline the knowledge about digital technologies and their potential and possibilities to operations management. Furthermore, the authors believe that identification of these technologies related to operations area can assist and guide to grasp how digital technologies and Industry 4.0 can enhance the efficiency of the operations in enterprises. Although, there are many manufacturers who are not ready for Industry 4.0 and digital transformation since they are only qualified enough to digitize specific areas in their operations (Ghobakhloo, 2018).

"Limited Financial Resources" is underlined as a significant barrier for SMEs regarding their Industry 4.0 transformation in many studies (Jovanovski et al. 2019; Sarvari et al. 2018; Stentoft et al. 2019; Sung 2018). However, findings show that limited financial resources are less important compared to lack of digital strategy barrier, lack of knowledge and awareness about Industry 4.0 barrier and operational use of digital technologies and lack of operational processes barrier.

6. Conclusion

This study provides valuable insights regarding Industry 4.0 barriers that SMEs may face during their transformation. Emerging technologies bring great opportunities for industrial developments and pave the way for the implementation of Industry 4.0 (Wan et al., 2016). SMEs that adopt Industry 4.0 will succeed in increasing their competitive advantages and minimizing risks. It is recommended that SMEs gain an interdisciplinary approach and that employees take part in activities that will make them more creative, innovative, and competent in technical/complex jobs. The trend towards open innovation makes this possible especially for businesses (Pereshybkina et al., 2017). Regarding digital transformation, the biggest challenge is the first step for many firms (OECD, 2021). Although it should be noted that supporting SMEs through proper programs is of great importance for developing countries (Başçı and Durucan, 2017) and Turkey is categorized as a developing country in terms of economy (Gergin et al., 2019). According to the Digital Transformation Index of TÜBİSAD (2020), Turkey's index is calculated as 3.06 (out of five) in 2020, compared to 2.94 in 2019, the index value is considered as "average" globally. Turkey is one of the countries where employment is largely based on SMEs. For this reason, it is important for SMEs to follow technological developments closely and focus on R&D activities to increase their productivity and international competitiveness. As a result of the adoption of Industry 4.0 and its technologies, SMEs will be able to complete their digital transformation and offer products and services with high added value.

In this study, AHP, a well-known method, was applied to a partially new subject. However, it is important to mention the weight of barriers as they may change depending on the sector(s) and the country in which SMEs operate. Despite all experts in the study being from Turkey, the Industry 4.0 Transformation Barriers stated in this study are somewhat general. Furthermore, the AHP method hypothesizes all criteria are independent which may not always be the case. For future studies, evaluation of sector-specific barriers and application of DEMATEL method on the barriers is recommended as DEMATEL method includes both direct and indirect effects, it can reveal cause and effect relationships between the barriers.

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