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ADVANCED TECHNOLOGICAL APPLICATION AND NEW HAZARDS

Onur DOĞAN[1*]

[1]Gümüşhane Üniversitesi, Meslek Yüksekokulu, İş Sağlığı ve Güvenliği Programı
ORCID No: http://orcid.org/0000-0001-8231-9872

Keywords

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Abstract

Integrating a technology into a business and making it sustainable can be achieved with a good analysis and a systematic workplace organization. Elements such as the internet of things, artificial intelligence, embedded software, and competent employee presence are the supporting elements of this process. Every technology has emerged as a result of human needs. Parallel to this, while living standards, production capacity and income level have increased, the need for labor has left its place to machines. However, as in every technological change process, some new risks and dangers are expected to emerge in this process. Analyzing these risks with traditional methods can be difficult and time consuming. Sustainability of production in an enterprise can be achieved by eliminating possible risks or reducing them to an acceptable level. Based on this determination, in this study, new and advanced technological risks are handled with a different method. In the study, the Analytical Hierarchy Process (AHP) method, which is one of the Multi-Criteria Decision Making (MCDM) methods and is widely preferred, was used. In the study, advanced technological applications and the risks they bring were determined by taking the opinions of experts. Accordingly, technological work accidents, occupational diseases, cyber-attacks, human-induced accidents are the main criteria, automation and robot accidents, chemical and biological origin occupational diseases, sabotage and attacks on personal data, misinterpretation of data / shortage of qualified employees are sub-criteria. determined. Microsoft Excel was used in the solution of the application and the results of each analysis were consistent. According to the results of the analysis, the most important criterion among the advanced technological applications and the risks they bring is occupational diseases (K2) with 0.4755, while in the binary comparisons made between the sub-criteria based on the main criteria, 0.3518 Sabotage and Attacks on Personal Data (Sub-Criteria 3) is the most important criterion. was the sub-criterion with high weight.

İLERİ TEKNOLOJİK UYGULAMALAR VE YENİ TEHLİKELER

Anahtar Kelimeler

Endüstri 4.0 ve Yeni Riskler, Analitik Hiyerarşi Proses Yöntemi (AHP), Meslek Hastalıkları ve İş Kazaları, İleri Teknolojik Uygulamalar

Öz

Bir teknolojinin işletmeye entegre edilmesi ve sürdürülebilir hale gelmesi, iyi bir analiz ve sistemli bir işyeri organizasyonu ile sağlanabilir. Nesnelerin interneti, yapay zekâ, gömülü yazılım, yetkin çalışan varlığı gibi unsurlar bu sürecin destekleyici unsurlarındandır. Her teknoloji insanoğlunun gereksinimi sonucu ortaya çıkmıştır. Buna paralel olarak yaşam standartları, üretim kapasitesi, gelir düzeyi artarken, işgücüne olan gereksinim yerini makinelere bırakmıştır. Ancak her teknolojik değişim sürecinde olduğu gibi bu süreçte de bir takım yeni risk ve tehlikelerin ortaya çıkması beklenmektedir. Bu risklerin geleneksel yöntemlerle analiz edilmesi zor ve ciddi zaman kaybına neden olabilir. Bir işletmede üretimin sürdürülebilirliği muhtemel risklerin ortadan kaldırılması veya kabul edilebilir düzeye indirilmesiyle sağlanabilir. Bu tespitten yola çıkarak yapılan bu çalışmada yeni ve ileri teknolojik riskler farklı bir yöntemle ele alınmıştır. Yapılan çalışmada Çok Kriterli Karar Verme (ÇKKV) yöntemlerinden olan ve yaygın olarak tercih edilen Analitik Hiyerarşi Proses (AHP) yöntemi kullanılmıştır. Çalışmada ileri teknolojik uygulamalar ve getirmiş olduğu riskler uzman kişilerin görüşleri alınarak belirlenmiştir. Buna göre, teknolojik iş kazaları, meslek hastalıkları, siber saldırılar, insan kaynaklı kazalar ana kriterler olarak, otomasyon ve robot kazaları, kimyasal ve biyolojik kaynaklı meslek hastalıkları, sabotaj ve kişisel verilere yönelik saldırılar, verilerin yanlış yorumlanması/ nitelikli çalışan azlığı ise alt kriterler olarak belirlenmiştir. Uygulamanın çözümünde Microsoft Excel kullanılmış ve yapılan her bir analiz sonucu tutarlı çıkmıştır. Yapılan analiz sonucuna göre, ileri teknolojik uygulamalar ve getirmiş olduğu riskler arasında önem düzeyi en yüksek kriter 0.4755 ile meslek hastalıkları (K2) olurken, ana kriterlere bağlı alt kriterler arasında yapılan ikili karşılaştırmalarda ise 0.3518 Sabotaj ve Kişisel Verilere Yönelik Saldırılar (Alt Kriter 3) en yüksek ağırlığa sahip alt kriter olmuştur.

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* Sorumlu yazar; e-posta: onur.dogan5065@gmail.com

1. Introduction

As we enter the 30th year of the 21st century, rapidly increasing digitalization in almost all areas of the industrial world has brought great change. The equivalent of this change in the industry and in the business, world is defined as Industry 4.0 or the Fourth Industrial Revolution (Dengiz, 2017). Industry 4.0 is based on the idea that all units in a business are digitized as necessary and everything becomes connected (https://www.gartner.com) and consists of a number of components. These components are simulation, cyber security, horizontal/vertical integration, augmented reality, big data and data analytics, cloud computing, 3D printers and robots. The Internet of Things (IoT), sensor technologies (Milinković et al. 2014), information technologies (IT) and cheapening of telecommunication technologies made information costs considerably cheaper. IoT is basically non-computer systems that exchange data via internet protocol (Rüßmann et al. 2015). IoT is one of the most important components for the realization of the concept of Industry 4.0. (Ray, 2016). In today's world, IoT technology makes everything more connected and enables the instant flow, storage and analysis of millions of data.

The great change in modern industrial processes with Industry 4.0 has led to the reshaping of jobs in many fields such as logistics, manufacturing, retail, and health (Dengiz, 2017). For instance, efficiency in production systems increased with augmented reality applications by using smart phone and smart glasses technologies (Yavuz, 2021). Humans and robots can work together using machine-human interfaces thanks to smart sensors. Robots can also be used in areas where logistics, production and office tasks are carried out, and jobs that require remote access can be controlled (Bahrin et al. 2016). In addition, instant environment monitoring can be done in toxic atmospheric work environments and in risky and dangerous places with high temperatures without the need for labor. In today's world, people making this process sustainable revealed the need to overcome certain problems such as more raw material, energy, infrastructure, qualified employees, initial investment cost, occupational health and safety.

For this reason, it is believed that a systematic analysis study can relatively reduce the risks of businesses on their way to Industry 4.0. For this purpose, the AHP method was employed in this study to identify and prioritize risks within the scope of Industry 4.0. The AHP method was introduced by Thomas L. Saaty in 1977. The method is a multi-criteria decision-making one enabling comparison between more than one alternative for a specific purpose. It is used by decision makers to solve complex problems (Gülenç and Bilgin, 2010). The present study consists of three sections. The first section presents the conceptual framework, the second part presents the study method, and the third section presents the study results and recommendations. The literature review on the study subject of the study put forth there are very few studies on Industry 4.0 and occupational safety. Furthermore, no study that ranked the risks brought by Industry 4.0 technologies using the AHP method was found. Accordingly, taking into consideration of expert views and recommendations in the field, four criteria and four alternatives were determined for the prioritization of risks brought by Industry 4.0. The criteria and sub-criteria developed within the study were applied to the senior executives working in strategic institutions in Turkey's Industry 4.0 path. The results were determined to be consistent. In light of these data, some recommendations are presented in the Results section.

It is seen positively in modern design in industrial life. The replacement of the workforce by machine-based technologies; It has brought many advantages such as increased capacity, energy savings in the industry, and less costly production. On the other hand, it is predicted that increasing complexity may leave employees vulnerable to unproven risks. At this point, it is thought that studies on possible risks in the future will be of great importance. For example, almost all occupational safety practices applied in workplaces today consist of experiences gained as a result of work accidents in the past.

This study, on the other hand, was applied to the top managers (total of five managers) of Turkey's leading technology companies, taking into account the literature research and expert opinions. The results of the analysis were shared with the participants. In the literature, it is possible to come across many studies covering occupational accidents, occupational safety practices, and accident analysis. However, there is almost no study on the analysis of the risks brought by advanced technological applications with the AHP method. At this point, it is expected that the study will make a significant contribution to the literature.

2. Occupational Safety and Health

Occupational health and safety is defined as scientific and systematic studies carried out to protect from situations that may harm both health and safety, which occur due to different reasons during the execution of work in the workplace (Karaman et al. 2011). Security also means staying-being-safe. In a more general sense, it can be defined as the detection

of existing security risks and keeping them at acceptable levels within a certain period (İşler 2013). Occupational Health is the activities carried out to ensure a complete physical, mental or social well-being of an individual (Yiğit, 2013). Occupational accident, literal meaning, is defined as a bad event with the potential to damage life or property. An accident is a physical or psychological event that cannot be determined where, when and how (Emiroğlu, 2001).According to Article 14 of occupational disease in the Social Insurance and General Health Insurance Law (SSGSSK); It has been defined as "temporary or permanent illness, physical or mental disability due to a reason arising from the nature of the work that the insured is working or doing, or due to the execution of the work" (SSGSSK, 2006).

Developing world order, increasing consumption frenzy has led to an increase in production capacity and the need for new technology. The change in production has led to an increase in complexity. Horizontal-vertical integration, artificial intelligence, and the replacement of robots on production lines increase complexity day by day. This situation is still a matter of debate, as it leaves employees vulnerable to new risks.

3. Advanced Practice Application

Advanced technologies have caused changes in the production methods, management systems, production design and production manufacture. Thanks to these technologies, improvements can be made for higher quality, efficiency and productivity compared to traditional production methods (Demirci et al. 2008). The concept of advanced technology production includes the technologies used in all stages, from the computer used for design to the workbench and equipment used in the production process (Semiz, 2004). Today, the majority of businesses aim to maintain their global competitiveness and take it to an advanced level. The concept of Industry 4.0 and its components, which emerged in 2011, play an important role for every business in this respect.

The Fourth Industrial Revolution is a movement that is fed from a transformation mentality or understanding and shows continuous development. The purpose of this perspective is to make production more effective and efficient thanks to the opportunities and innovation provided by digitalization (Dengiz, 2017). At this point, the right choice of the technology planned to be invested will also form the infrastructure of the technological breakthroughs that the business will make in the future. In the integration process, the compatibility of the new technologies with the existing technologies in the business should not be ignored because any integration problem concerning the old and new technology will create in practice may cause these technologies to be disabled (Güleş and Çağlıyan, 2003).

Industry 4.0's efficient and harmonious operation of industry use is built on nine components. These are Simulation, Autonomous Robots, Cyber Security, Additive Manufacturing, Augmented Reality, Big Data, Industrial Internet of Things, Horizontal Integration and Vertical Integration (Gönen et al. 2021).

Cyber Physical Systems (SFS): SFSs are the main components of Industry 4.0. By means of sensors, the attitudes and behaviors of objects are transferred to the cyber system via the internet network (Alçın, 2016).

Horizontal and Vertical Integration: Vertical integration is the provision of uninterrupted information flow at all stages of production processes by using network connections. Horizontal integration refers to the uninterrupted connection flow both within the enterprise and between different enterprises (Serinikli, 2018).

Simulation: It is a modelling method developed to monitor all the data of a physical system existing in the real world by transferring it to the virtual environment. Simulation provides an opportunity for possibilities to be followed in advance in the virtual environment and to make the necessary preparations (Çelen, 2017).

Robots: Robots are machines that function by communicating with connected devices via sensors with the installed smart or embedded software. Today, robots are mostly used in production lines where repeatable work is done.

Internet of Things: IoT is the communication of objects with certain protocols in a common network (Görçün, 2016). Real-time data flow can be provided between every machine, device and equipment connected to IoT.

Cyber Security: Connected systems with remote access store their data in spaces such as the cloud system. The healthy transfer and protection of this data requires maximum security (Serinikli, 2018). If the data is easily accessible and the security protocols are not given sufficient importance, data loss may occur. This, in turn, may result in troubles for the business, such as the use of the business's trade secrets by unwanted persons or loss of business's trade secrets.

Augmented Reality: Augmented reality refers to the reality environment in which digital products and real-world objects are used (Milgram and Kishino, 2016). This technology is classified into two categories, namely optimal based technologies and video-based technologies. The main difference between them is the scene that is formed from the merging of the virtual and real worlds (Somyürek, 2014).

Big Data: This concept refers to the whole of semi-structured, structured and unstructured data produced in large volume, speed and diversity. In many industrial areas, big data is sourced by digitizing existing data or generating new data (Aktan, 2018).

3D Printers: 3D printers are the machines that transform the three-dimensional data in the computer into objects (Davutoğlu et al. 2017). They are mostly used for the production of any product portable before mass production.

4. Technologies Within the Scope of Industry 4.0

The 4th Industrial Revolution is not just a technological issue. The development that comes by ignoring the human factor will bring along significant problems (Sayar and Yüksel, 2018). It is believed that, unlike the three industrial revolutions of the past, Industry 4.0 may affect the ecosystem in many ways, due to new work accidents, occupational diseases and environmental pollution caused by industrial wastes. The predictability of these risks is of great importance both for the people of today's world and for the next generation. Automation and robot accidents, chemical and biological risks, sabotage and attacks on personal data, misinterpretation of data or lack of qualified employees are some of the problems we hear frequently, especially in recent years and are expected to emerge as issues that require solution-oriented approaches in the industry 4.0 process.

Automation and Robot Accidents: Robot-human interaction has become one of the indispensable elements of our daily life thanks to the developments in recent years (Fong et al. 2019). Automation and robots minimized the need for labor for heavy and repetitive work in industry. This, in turn, minimizes the need for labor, physical fatigue and injuries. Robots can pose serious risks to human safety in some cases. Robots can cause serious accidents while being guided from one point to another. For this reason, in the last two decades, by using different sensors and information processing methods, solutions have been sought for security problems (Bingol and Aydoğmuş, 2019).

Chemical and Biological Risks: Chemicals are one of the indispensable elements of our daily life. All living and non-living matter consists of chemical substances. When chemicals are used as needed and in moderation, they improve the quality of life, health and well-being. However, if they are managed incorrectly and dangerously, they can pose a serious risk to the environment and health. There are 5-7 million known chemical substances of various types worldwide. Every year, 400 million tons of chemicals are produced to be used in different sectors. In 2001, 1200 new chemicals were produced in North America alone (Güven, 2012). It is estimated that between 5,000 and 7,000 chemicals found in nature are harmful (Safetyhealth.com.tr). Workers can be exposed to many occupational risks due to toxic substances originating from the workplace environment, the machines used, and the work they do that are not appropriate for human nature (İlhan et al. 2006). According to the data of the World Health Organization (WHO), 11 million new cases of occupational diseases encountered every year. As a result of these cases, approximately 700 thousand occupational patients lose their lives (Yavuz and Erdoğan, 2001). Today, issues such as the wide variety of products, the complexity of technology and organizational structure, and the lack of attention to occupational safety cause many work accidents and occupational diseases (Tarım, 2017). We spend a significant part of our lives in the work environment by being exposed to physical and chemical risks as well as biological risks. Among the biological risks, bacteria, parasites, fungi, viruses and ticks come to the fore. While physical and chemical risks have limit values for humans, this is not true for biological risks. Biological risks begin to multiply from the moment they enter the human body. They can show different behaviors in various physicochemical environments. An example of this is the mutation of the SARS-CoV-2 virus, to which human beings have been exposed since January 2020. The rapid spread of these risks with very few factors and their transformation into a disease pose a serious risk (Alıcı et al. 2020). Since COVID-19 is a global disease, it has been declared a pandemic by the WHO. It poses a serious threat to work life as well as daily life. More than 59 million healthcare workers (Walker et al. 2004) working in the health system worldwide are at risk due to the pandemic (Ağar, 2021).

Sabotage and Attacks on Personal Data: Developments in information technologies have made access to information much easier and faster. However, the reliability and security of the accessed information has also become more difficult. With the use of information systems in all areas of our lives, the need for cyber security for these technologies has increased (Yıldırım, 2018). In today's world, cyber-attacks pose a serious risk for cyber security. Individuals and institutions noticing these threats

(Distributed Denial of Service [DDOS]), ransomware, Phishing attacks, etc.) will help them predict what extent the techniques and methods of target attacks can reach (Miller, 2016) and how much damage they can cause. In this sense, particularly, institutions should develop cyber security policies against such risks. Certain security policies ensuring the control of cyber security should be developed (Yılıdırm, 2018).

Misinterpretation of Data and Lack of Qualified Employees: The development of humankind has revealed the need for industrial revolutions. With this change, the demand for traditional labor force was replaced by capital. The concept of Industry 4.0, introduced in Germany in 2011, also revealed the need for new business models and workforce for different competencies (Doğru and Mecik, 2018). The effect of the use of robots in automated and sensor factories on the workforce in the future is considered as one of the biggest problems of the process (Gürsakal, 2017) because labor-intensive production in the industry will leave its place to smarter systems.

5. The Analytic Hierarchy Process Method

The analytic hierarchy process (AHP) method was first introduced by Alpert and Myers in 1968. Later, it was developed as a model by Thomas Lorie Saaty in 1977 and used to solve decision-making problems (Yaralıoğlu, 2001). The AHP method refers to an approach that logically combines individual's experience, knowledge, intuitions and thoughts (Chin et al. 1999). Multi-criteria decision-making (MCDM) is used to rank the problems in order of importance, weight or priority, taking into account the most appropriate criterion among different alternatives. This method is based on the process of modeling and analysis according to criteria in the decision-making processes (Gülenç and Bilgin, 2010). The AHP method has a hierarchical structure which has the goal at the top and at least three levels at the bottom. Below the goal, there are main criteria and sub-criteria, if any. At the bottom of the hierarchy, there are alternatives (Saaty, 200; Özbek and Eren, 2012). The AHP method allows the elements included in the process to be retested. In the analysis of the method, in order for the criteria to be consistent, the number of criteria should be determined and defined correctly. The following steps are followed in solving a problem using the AHP method. First, the problem is defined. Then, the criteria are identified, and alternatives are determined. Next, a hierarchical structure is developed. Later, a pairwise comparison matrix is created. Finally, a consistency check (sensitivity analysis) is performed (Özbek and Eren, 2012).

Table 1. Comparison Scale (Saaty, 1980**)**

Intensity of Importance	Definition	Explanation
1	Equal importance	Two alternatives have equal importance
2	Weak	
3	Moderate importance	One criterion is slightly favored compared to the other one
4	Moderate plus	
5	Strong importance	One criterion is strongly favored compared to the other one
6	Strong plus	
7	Very strong importance	One criterion is very strongly favored compared to the other one
8	Very, very strong	
9	Extreme importance	Ne criterion being extremely important compared to the other one is based on various information
Reciprocal values	If a value (x) is assigned when comparing i,j; the value to be assigned when comparing with j/I will be (1/x)	

Table 1 presents the table of intensity of importance used in the comparison. The table shows that the highest value of the scale is nine, while the lowest value is 1/9 (Vidya, 2006). Normalization of the pairwise comparison matrices: While creating the pairwise comparison matrices, the intersection point of the table is filled by the participants, whereas the lower part is calculated by taking the symmetry of the table. If more than one participant is included in the study, the geometric mean of the value given by each participant is determined and each column is summed. Each criterion is then normalized by dividing it by the column total. Equation 1 is used in the calculation (Özbek and Eren, 2012).

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (1)$$

Equation 2 is used to calculate the priority vector (Özbek and Eren, 2012).

$$w_i = \left(\frac{1}{n}\right)\sum_{j=1}^{n} a'_{ij} \quad (2)$$

Equation 3 is used to calculate the consistency index (CI).

$$CI = \frac{\left(\lambda_{\max} - n\right)}{\left(n-1\right)} \quad (3)$$

In order to calculate the consistency index, the Eigenvalue, λ_{max} must be calculated. Equation 4 is used to calculate the eigenvalue.

$$\lambda_{\max} = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{\sum_{j=1}^{n} a_{ij}.w_j}{w_i}\right) \quad (4)$$

In order to calculate the consistency index, the Random Index (RI) must be determined. The number of n is taken into account in determining the RI.

Table 2. Random Index (Satty, 1980**)**

n	1	2	3	4	5	6	7	8
R1	0	0	0.58	0.90	1.12	1.24	1.32	1.41

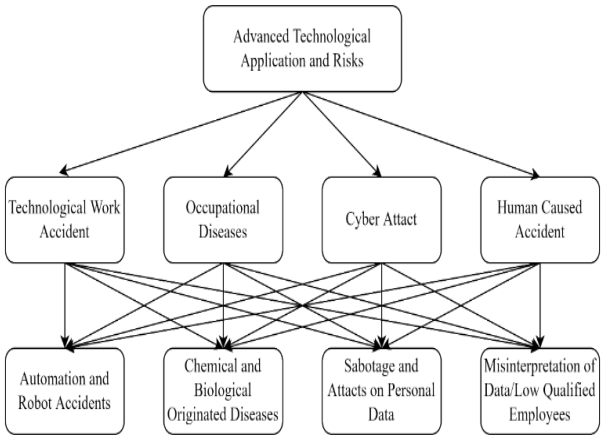
$$CR = \frac{CI}{RI} \quad (5)$$

In order for the obtained result to be consistent, the CI should be 0.1>CR small (Özbek and Eren, 2012).

6. Application

The AHP method is a method in which individuals' experience, knowledge and intuition are logically integrated (Chin et al. 1999). At the same time, it is to determine the importance levels, weight or superiority of the problems encountered in MCDM problems in order to choose among multiple alternatives. The AHP method is a MCDM method that can be used effectively in solving these problems. Both objective and subjective thoughts of the participants can be included in the decision process. In this respect, it is a mathematical method that evaluates the quantitative and qualitative variables together, which includes the decision-making processes of groups and individuals in the analysis (Gülenç & Bilgin, 2012). This study was conducted to determine the priority order of the risks brought by current technological applications within the scope of Industry 4.0. The AHP method was employed in the study. The criteria and sub-criteria used in the method were developed by taking into account the opinions and recommendations of field experts. The study consists of four main criteria and four sub-criteria. Each main criterion (C1 Technological Work Accidents, C2 Occupational Diseases, C3 Cyber Attack, C4 Human-Induced Accidents) was compared among themselves and the intensity of importance and consistency were determined. This procedure is repeated using pairwise comparison for sub-criterion of each main criterion (Sub-Criteria 1 Automation and Robot Accidents, Sub-Criteria 2 Chemical and Biological Originated Diseases, Sub-Criteria 3 Sabotage and Attacks on Personal Data, Sub-Criteria 4 Misinterpretation of Data and Lack of Qualified Employees).

Figure 1. Decision Hierarchy Regarding the Problem



Advanced Technological Applications and Risks Brought by Them Technological Work Accidents, Occupational Diseases, Cyber Attack, Human-Induced Accidents Automation and Robot Accidents, Chemical and Biological Originated Diseases, Sabotage and Attacks on Personal Data, Misinterpretation of Data and Lack of Qualified Employees Figure 1 presents the decision hierarchy regarding the study problem. Accordingly, the hierarchical structure is made up of criteria and four sub-criteria that are believed to be closely related to these criteria.

Table 3. Criterion Used in Binary Comparison

Criteria	C.1	C.2	C.3	C.4
C.1	1	0.2012	0.6349	0.6799
C.2	4.9701	1	1.6918	2.6846
C.3	1.5750	0.5911	1	0.7785
C.4	1.4701	0.3725	1.2845	1
Total	**9.0152**	**2.1648**	**4.6112**	**5.143**

Since more than one participant filled out the questionnaire, a matrix was created by taking the geometric mean of the value corresponding to each criterion (Table 3). Then, each column was summed up and written inside the total cell at the bottom of the column. In order to obtain the normalized matrix, each criterion was divided by the column sum and Table 4 was created.

Table 4. Normalized Matrix

Criteria	C.1	C.2	C.3	C.4	Criteria Weights (W)
C.1	0.1109	0.0929	0.1377	0.1322	0.1184
C.2	0.5513	0.4619	0.3668	0.5220	0.4755
C.3	0.1747	0.2730	0.2169	0.1514	0.2040
C.4	0.1631	0.1722	0.2786	0.1944	0.2021
Total	1	1	1	1	1

In order to calculate the criterion weights, each column is summed and averaged. Thus, the weights of all criteria are calculated (Table 4).

Table 5. Priority Vector Calculation

Criteria	C.1	C.2	C.3	C.4	Total
C.1	0.1184	0.0957	0.1295	0.1374	0.4810
C.2	0.5858	0.4755	0.3451	0.5425	1.9489
C.3	0.1865	0.2811	0.2040	0.1573	0.8289
C.4	0.1740	0.1771	0.2620	0.2021	0.8152

In order to calculate whether the analysis is consistent or not, priority vector is calculated (Table 5). Each line is summed up and written inside the total cell. Each priority vector is then divided by the criterion weight. By taking the mean of the obtained values, Lamda Max. value is calculated. Finally, the Random Index value is checked. Since the number of criteria in the study is four (n:4), the Random Index value is 0.90.

Table 6. Consistency Index

Total	W	T/W	Average	Lamda Max.
0.4810	0.1184	4.0625	4.0664	Consistency İndeks
1.9489	0.4755	4.0986		0.0221
0.8289	0.2040	4.0632		Rassal İndex
0.8152	0.2021	4.0336		0.0221/ 0.9(RI)
Total		16.2579		0.1>0.02455

In the study analysis, the analysis was performed by using Microsoft Excel. The consistency ratio was found to be 0.1>0.02455. Thus, the result was consistent. This procedure was repeated for each sub-criterion and the following values were obtained.

Table 7. Technological Work Accidents Sub-Criteria Comparison

Technological Work Accidents Sub Criteria (T.W.A.S.C)	T.W. A. S. C. 1	T.W. A. S. C. 2	T.W. A. S. C. 3	T.W. A. S. C. 4
T.W. A. S. C. 1	1	0.9260	0.25	0.4080
T.W. A. S. C. 2	1.080	1	0.4083	0.8161
T.W. A. S. C. 3	4	2.4492	1	0.5771
T.W. A. S. C. 4	2.4511	1.2253	1.7328	1
Total	8.5311	5.6005	3.3911	2.801

Table 7. presents the comparison of the sub-criteria created due to technological work accidents. Since more than one participant was included in the study, the matrix was obtained after the geometric mean of the value corresponding to each criterion was determined

Table 8. Normalized Matrix

Sub Criteria	T.W.A.S. C. 1	T.W.A.S. C. 2	T.W.A.S. C. 3	T.W.A.S. C. 4	W	All Priorities Vector Account	Av.	Lamda Max.
T.W.A.S. C. 1	0.1172	0.1653	0.0737	0.1457	0.2038	0.1255	4.2015	**Con.İndeks**
T.W.A.S. C. 2	0.1266	0.1786	0.1204	0.2913	0.5843	0.1792		**0.0671**
T.W.A.S. C. 3	0.4689	0.4373	0.2949	0.2060	0.0492	0.3518		**Rassal İndeks**
T.W.A.S. C. 4	0.2873	0.2188	0.5110	0.3570	0.1627	0.3435		**0.0671/09(RI)**
Total	1	1	1	1	1			0.1>0.0746

In Table 8, each criterion was divided by the column total. Then, each row was summed and averaged. Thus, the normalized matrix was obtained. Next, priority vector was calculated and finally the consistency index was calculated. This procedure was applied for all the sub-criteria (Table 9,10, 11).

Table 9. Consistency Index of Occupational Diseases

Occupational Diseases Sub Criteria (O.D.S.C)	O.D.S. C. 1	O.D.S.C. 2	O.D.S. C. 3	O.D.S. C. 4	W	All Priorities Vector Account	Av.	Lamda Max.
O.D.S. C. 1	0.1635	0.2502	0.1310	0.1228	0.1668	0.7051	4.214	**Consistency İndeks**
O.D.S. C. 2	0.1829	0.2797	0.2548	0.4910	0.3022	1.2933		**0.0715**
O.D.S. C. 3	0.4223	0.3712	0.3381	0.2126	0.3361	1.4065		**Rassal İndeks**
O.D.S. C. 4	0.2313	0.0989	0.2761	0.1736	0.1949	0.8121		**0.0715/09(RI)**
Total	**1**	**1**	**1**	**1**	**1**			0.1>0.0795

Table 10. Consistency Index of Cyber-Attacks

Cyber-Attacks Sub Criteria (C.A.S.C.)	C.A. S. C. 1	C.A. S. C. 2	C.A. S. C. 3	C.A. S. C. 4	W	All Priorities Vector Account	Av.	Lamda Max.
C.A. S. C. 1	0.2238	0.1836	0.2265	0.2660	0.2250	0.9050	4.0343	Consistency İndeks
C.A. S. C. 2	0.2888	0.2370	0.1985	0.2377	0.2405	0.9686		0.01142
C.A. S. C. 3	0.2636	0.3144	0.2668	0.2303	0.2688	1.0919		Rassal İndeks
C.A. S. C. 4	0.2238	0.2650	0.3082	0.2660	0.2658	1.070		0.01142/09(RI)
Total	**1**	**1**	**1**	**1**	**1**			0.1>0.0127

Table 11. Consistency Index of Human-Induced Accidents

Human-Induced Accidents Sub Criteria (H.A.S.C.)	H.A.S. C. 1	H.A.S. C. 2	H.A.S. C. 3	H.A.S. C. 4	W	All Priorities Vector Account	Av.	Lamda Max.
H.A.S.C. 1	0.2498	0.2884	0.1717	0.2921	0.2505	1.0179	4.0493	Consistency İndeks
H.A.S.C. 2	0.2040	0.2355	0.2171	0.2697	0.2316	0.9450		0.02642
H.A.S.C. 3	0.2964	0.2210	0.2037	0.1461	0.2168	0.8819		Rassal İndeks
H.A.S.C. 4	0.2498	0.2551	0.4075	0.2921	0.3011	1.2362		0.02642/0.9(RI)
Total	**1**	**1**	**1**	**1**	**1**			0.1>0.0294

7. Analysis Results and Discussion

In the analysis of the study, all stages of the method specified in the methodology were carried out appropriately. While there are some uncertainties in the determination of the problem (technologies with proven risks), the criteria titles are kept broadly, while the selection of the sub-criteria is made by reducing it to the specific. In the study, the negative effects of the technologies used on the workforce were taken into account while selecting the criteria and sub-criteria. Especially in recent years, uncertainty about the possible risks of technologies such as 5G, robot-cobot, artificial intelligence, dark factory has formed the aim of the study. Therefore, study; It was applied to factory managers with high competence and advanced technologies. The subject of the study is the unproven risks in the future. The most important reason for choosing the AHP method in the study is that this method includes objective and subjective decisions, and the answers are based on the knowledge and experience of the participants. The AHP method is comparatively more advantageous than other methods in that it allows checking the consistency of the analysis results in its solution. However, any changes to the criteria or sub-criteria require the analysis to be recalculated. The fact that there are many pairwise comparisons causes a serious loss of time in the calculation of the analysis. The fact that the decision makers have a significant influence on the decision can cause them to make wrong assessments and take wrong decisions. The competence levels of the expert opinions are not sufficient, and in some cases, it may be necessary to increase the number of expert opinions (Mutlu and Sarı, 2017; Cheng, 1996).In Table 12, the results of the comparison analysis between the criteria and sub-criteria are given. According to the comparison between the main criteria, the criterion with the highest weight was occupational disease with 0.4755. This is listed as 0.2040 cyber-attacks, 0.2021 human-induced accidents and 0.1184 technological work accidents, respectively. The following results were obtained in

the comparisons made between the sub-criteria based on the main criteria: The highest criterion among the sub-criteria related to the occupational disease criterion was 0.3361 Sabotage and Attacks on Personal Data. Among the sub-criteria related to the Cyber Attack main criterion, the highest-weighted sub-criterion was Sabotage and Attacks on Personal Data with 0.2688. 0.3011 Misinterpretation of Data/Low Qualified Employees was the sub-criterion with the highest weight among the sub-criteria related to the main criteria related to human-induced occupational accidents. Among the sub-criteria related to the Technological Work Accidents main criterion, the sub-criterion with the highest weight was Sabotage and Attacks on Personal Data with 0.3518. According to the results of the analysis, the highest weighted criterion was occupational disease as a result of the comparison made between the main criteria, while the highest weighted sub-criterion was Sabotage and Attacks on Personal Data as a result of the comparison made between the sub-main criteria. In the literature, it is possible to reach a lot of information such as the risks, advantages and disadvantages of advanced technologies. For example, with the development of robot technologies in the recent past, workforce-robot cooperation has come to the fore (IFR, 2017). Instead of replacing the workforce, these robots provide benefits such as helping employee productivity and reducing risk. In a labor-intensive job at BMW's American factory in Spartanburg, robots helping to install moisture and sound isolation doors is a frequently mentioned collaboration practice (Fırat and Fırat, 2017). Internet-based connectivity in the business ecosystem will connect many elements in real time. Fast data flow will complicate the analysis of data, decision making processes. In addition, remote machine-equipment-employee-environment monitoring with internet-based network structure reveals the problem of cyber security. For this reason, machinery-tools-tools and smart sensors have increased cyber risks and turned into a more fragile structure against threats (Saldı and Selimoğlu, 2019). At this point, technological risk factors on databases in workplaces, risk analysis of cyber resources, threat and preparedness levels are among the important issues that should be emphasized (Yılmaz and Sağıroğlu, 2013). It is known that there are approximately six million chemicals in different uniforms around the world. Chemicals that are harmful and toxic can have cancer and lethal effects. Being in the same environment for a long time or working with chemicals such as heavy metals, gases and solvents can cause occupational diseases (Doğu et al., 2021).

Table 12. Criteria and Sub-Criteria Weights

Criteria	Criteria Weights (W)	Sub Criteria	Sub Criteria Weights (W)	Sub-Criteria Consistency Index
Technological Work Accidents (C.1)	**0.1184**	Automation and Robot Accidents	0.1255	01>0.0746
		Chemical and Biological Originated Diseases	0.1792	
		Sabotage and Attacks on Personal Data	**0.3518**	
		Misinterpretation of Data/Low Qualified Employees	0.3435	
Occupational Diseases (C.2)	**0.4755**	Automation and Robot Accidents	0.1668	01>0.0795
		Chemical and Biological Originated Diseases	0.3022	
		Sabotage and Attacks on Personal Data	**0.3361**	
		Misinterpretation of Data/Low Qualified Employees	0.1949	
Cyber Attact (C.3)	**0.2040**	Automation and Robot Accidents	0.2250	01>0.0127
		Chemical and Biological Originated Diseases	0.2405	
		Sabotage and Attacks on Personal Data	**0.2688**	
		Misinterpretation of Data/Low Qualified Employees	0.2658	
Human Caused Accident (C.4)	**0.2021**	Automation and Robot Accidents	0.2505	01>0.0294
		Chemical and Biological Originated Diseases	0.2316	
		Sabotage and Attacks on Personal Data	0.2168	
		Misinterpretation of Data/Low Qualified Employees	**0.3011**	

8. Conclusion and Recommendations

Technological developments in the industrial industry have deeply affected both our daily lives and the way we do business. This change, which is gaining momentum day by day, has also led to the emergence of some requirements. For example, the inclusion of technologies such as the dark factory, artificial intelligence, robot and cobot on the production lines has ensured that the production is more rapid and of higher quality. This situation has also increased the demand for more raw materials, competent workforce and energy requirements. Uncontrolled raw material production, short product life cycles, and the risk of new industrial residues for the environment and human health are among the main problems of this process. On the other hand, the use of information, communication and internet technologies in industry and the connection of all kinds of elements will cause employees to be affected much faster and more by radio frequency waves, radiation, dust-noise-vibration and chemical wastes.

In this study, the possible risks that may arise in the near future and the factors that may reveal these risks were made by using the AHP method by taking the literature and expert opinions. In data analysis of the study, Microsoft Excel was used. In the study, four criteria and four sub-criteria were examined. According to the study analysis, the CI of all criteria were found below 0.1. Accordingly, in the order of importance of advanced technological applications and the risks they bring, the most weighted risk was determined as occupational diseases (C-2) with 47.55%. This criterion was followed by cyber-Attack (C-3) with 0.2040, human-induced accidents (C-4) with 0.2021, and technological work accidents (C-1) with 0.1184. The results of the pairwise comparisons of the sub-criteria related to the main criteria showed that among the sub-criteria related to C-1, the most weighted sub-criterion was sabotage and attacks on personal data with 0.3518, among the sub-criteria related to the C-2 criterion, the most weighted criterion was sabotage and attacks on personal data with 0.3361, among the sub-criteria related to C-3, the most weighted criterion was sabotage and attacks on personal data with 0.2688, and among the sub-criteria related to C-4, the most weighted criterion was misinterpretation of data and lack of qualified employees with 0.3031. Today, most of the preventive and remedial applications for occupational health and safety emerged as a result of painful experiences in the past. In this process, which is also called the digital age, the risks faced by people are believed to be much greater and equally important than the accidents experienced in the past. For this reason, besides the advantages of Industry 4.0 and the technologies it brings, it is of great importance that the possible risks are proven and the degree of impact is predictable. It may be advisable for researchers who want to conduct studies in the future to investigate the effect of connected devices on workers (measurement of noise-vibration-dust exposure levels).

Conflict of Interest

No conflict of interest has been declared by the authors.

References

Ağar, A. (2021). Biological Risk Factor in Working life and Covid-19, *Journal of Public Health Nursing*, 3(2), 135.

Aktan, E. (2018). Big Data: Application Areas, Analytics and Security Dimension, *Information Management Journal*, 1(1), 1-20.

Alçın, S. (2016). A New Path for Production: Industry 4.0, *Journal of Life Economics*, (8), 19-30.

Alıcı, N.Ş. Beyan, A.C. and Şimşek, C. (2020). Covid-19 and Lungs: What Chest Diseases Specialist Need to Know, Covid-19 as an Occupational Disease. http://www.solunum.org.tr/TusadData/user files/file/EJP-EK-SAYI-COVID19-27042020.Pdf#Page=149.

Bahrin, M.A.K., Othman, M.F., Azli, M.F. Talib, (2016). Industry 4.0: A Review on Industrial Automation and Robotic, *Journal Technology*, (78), 6-13.

Bıngol, M.C. and Aydoğmuş, O. (2019). Development and Implementation of an Accessible Neural Network Based Software Using Multi-Channel Communication for Human Safety in Human-Robt İnteraction, *Fırat University Eng. Know Magazine*, 31(2), 489.

Çelen, S. (2017). Industry 4.0 and Simulation, *International Journal Of 3d Printing Technologies and Digital Industry* 1(1), 10.

Cheng, C. H. (1996). Evaluating Naval Tactical Missile Systems by Fuzzy AHP Based on the Grade Value of Membership Function. *European Journal of Operational Research. Vol.* 96, no 2. pp. 343-350.

Chin, K.S., Chiu, S. & Tummala, V.M.R. (1999). An Evaluation of Success Factors Using the AHP to Implement ISO 14001-Based EMS, *The*

International Journal of Quality and Reliability Management, 16(4), 341-361.

Davutoğlu, N.A., Akgül, B. and Yıldız, E. (2017). Ensuring Change Effectively by Creating Awareness with the Concept of Industry 4.0 in Business Management, *Academic Journal of Social Studies*, 5(52), 544-567.

Demirci, R., Semiz, S. ve Gölcü, M. (2008), Use of Advanced Technology and Competition in Businesses: A Field Study in the Automotive Industry, *Journal of Polytechnic*,1(2), 139.

Dengiz, O. (2017). Industry 4.0: Concept and Perception Revolution in Production. *Journal of Machine Design and Manufacturing*,15(1), 38.

Doğru, B.N. and Mecik, O. (2018). The Effects of Industry 4.0 on the Labor Market in Türkiye: Firm Expectations, *SDU Faculty of Economics and Administrative Sciences*, (23),

Doğu, U. C., Boz, S. & Ünver, M. (2021). Occupational Health and Safety with Autonomous Systems in the Transport of Hazardous Materials in the Chemical Industry. *Journal of Advanced Engineering Studies and Technologies*, 2 (1), 1-9.

Emiroğlu, C. (2001). In the Working Environment Accidents and Occupational First Aid, 23, Ankara: Turkish Business Publications.

Fırat, O. Z. & Fırat, S. Ü. (2017). Industry Trends and Robots in Journey 4.0. *Journal of Istanbul University Faculty of Business*, 46 (2), 211-223.

Fong, J., Rouhani, H. and Tavakoli, M. (2019). A Therapist-Taught Robotic System for Assistance During Gait Therapy Targeting Foot Drop, *IEEE Robot. Autom. Lett.*, 4(2), .407-413.

Gartner, https://www.gartner.com. Date of Access:23.01.2022.

Gönen, S., Yılmaz, E. N., Şanoğlu, S. Karacayılmaz, G. and Özbirinci, Ö. (2021). Forgotten Component in the Development Process of Industry 4.0: Cyber Security. *Duzce University Journal of Science and Technology*, 9 (4), 1142-1158.

Görcün, Ö.F. (2016). Fourth Industrial Revolution Indusrty 4.0, *Beta Publishing*, (İstanbul).

Gülenç, İ. F. and Aydın Bilgin, G. (2010). Yatırım Kararları İçin Bir Model Önerisi: AHP Yöntemi – A Model Proposal for Investment Decisions: AHP Method *Marmara Üniversitesi Öneri Dergisi*, 9 (34), 97-107.

Güleş, H.K. and Çağlıyan, V. (2003). The Effect of Using Advanced Manufacturing Technologies on Business Performance: An Application in Small and Medium-Sized Industrial Enterprises, *This Feas Journal of Social and Economic Research*,3(5), 77.

Gürsakal, N. (2017). Machine Learning and Deep Learning. *Dora Publish Distribution*, (Bursa).

Güven, R. (2012). Occupational Diseases in the World and in Our Country, Ankara, Ministry of Labour and Social Security, *General Directorate of Occupational Health and Safety*.

IFR (2017). Executive Summary World Robotics 2016 Industrial Robots.

İlhan, M.N., Kurtcebe, Z. Ö., Durukan, E., Koşar, L. (2006). Socio-Demographic Characteristic and Working Conditions of Cleaning Workers and Frequency of Work Accidents and Occupational Diseases, *Fırat University Health Sciences Medical Journal*, 20(6), 433-439.

İşler, M. C. (2013 Occupational health and Safety. The Effect of Training and Safety Culture on the Prevention of Occupational Accidents and Occupational Diseases. Assistant Labor Inspector Study Letter Ankara.

Karaman, E. A., Çivici, T. ve Kale, S. (2011). The Place and Importance of Occupational Health and Safety in the Construction Sector Çanakkale Publication No: 3041 2000-2005 *Dicle Medical Journal*, 34(4), 264-271.

Miligram, P. and Kishino, F. (2016). A taxonomy of mixed reality visual displays, *IEICE Transactions on Information Systems*, 77(12), pp.1321-1329.

Milinković, A., Milinković, S., L. Lazić (2014). Some experiences in building IoT platform, *22nd Telecommunications forum TELFOR, 1138-1141*, *Serbia, Belgrade*, Nov, 25-27.

Miller, K. L. (2016). About Reasonable Cybersecurity: A Proactive and Adaptive Approach, *The Florida Bar Journal*, 90:22.

Mutlu, M.and Sarı, M. (2017). Multi-Criteria Decision-Making Methods and Their Use in the Mining Industry. *Scientific Mining Journal*, 56 (4), 181-196.

Özbek, A. and Eren, T. (2012). Determination of Third Party Logistics (3PL) Firm by Analytical Hierarchy Process (AHS), *International Journal of Engineering Research and Development*, 4(2).46-54.

Ray, P.P. (2016). A Survey of IoT Cloud Platforms, *Future Computing and Informatics Journal*, 1(1-2), 35-46.

Rüßmann, M. Lorenz, P. Gerbert, M. Waldner, J.Justus, P. Engel, M. Harnisch (2015).

"Industry 4.0: The future of productivity and growth in manufacturing industries", *Boston Consulting Group*, 9(1), 1.

Saldı, M. H. & Selimoğlu, S. K. (2019). In the Analysis of Cyber Risks in Businesses, In Mapping and Evaluation Role of Internal Audit, *Accounting and Auditing Glance, 19* (57), 1-18 .

Sayar, M. and Yüksel, H. (2018). Industry 4.0 and Industry Transformation in the Turkish Public Sector, *Journal of Law and Economic Studies*, 10(2), 11.

Semiz, S. (2004). Strategic Technology Management in Enterprises Producing with Advanced Technology: A Field Study. Doctoral Thesis G. U. Graduate School of Natural and Applied Sciences, Ankara, pp.122-132.

Serinikli, N. (2018)."Impact of Industry 4.0 on Private, Public and Cooperative Sectors", *SDU Faculty of Economics and Administrative Sciences*, (23).1615.

Social Insurance and General Health Insurance Law (16.06.2006). No 5510, Official Gazette, 26200, 5, C: 45.

Somyürek, S. (2014). Attracting the Attention of Generation Z in the Teaching Process: Augmented Reality", *Educational Technology, Theory and Pratictive*, 4(1),63-80.

T.L. Saaty, (1980). The Analytic Hierarchy Process, *New York: McGraw-Hill*,

T.L. Saaty, T.L. (2000). Fundamentals of Decision Making and Priority Theory with The Analytic Hierarchy Process, Rws Publications, (6).

T.L. Saaty, T.L. (2008). Decision Making With the analytic Hierarchy Process, *Int. J. Services SCI*,.84-86.

Tarım, M. (2017). Occupational Accident and Occupational Diseases in the Chemical Industry, *Istanbul Commerce University Journal of Science*, 16(32), 49.

Vidya, O.S. (2006). Analytic hierarchy process: An overview of application, European Journal of Operational Research, (169),.1-29.

Walker, J. T., Bradshaw, D. J., Finney, M., Fulford M. R., Frandsen E., Østergaard E., ten Cate J. M., Moorer W. R., Schel A. J., Mavridou A., Kamma J. J., Mandilara G., Stösser L., Kneist S., Araujo R., Contreras N., Goroncy-Bermes P., O'Mullane D., Burke F., Forde A., O'Sullivan M. & Marsh P. D. (2004). Microbiological Evaluation of Dental Unit Water Systems in General Dental Practice in Europe. *European Journal of Oral Sciences,* 112, 412-418.

Yaralıoğlu, K. (2001). Analytical Hierarchy Process in Performance Evaluation, *Dokuz Eylül University İ.İ.B.F.*, 16(1), pp.129-142.

Yavuz, C.I. and Erdoğan, S. (2001). Chemicals at Work, *TTB Journal of Occupational Health and Safety*, 33.

Yavuz, O. (2021), The effect of interest level On Industry 4.0 Tool Used in Production on the Export of High-Tech Products, *Journal of Business Studies*,13(1), 825-843.

Yiğit, A. (2013). Occupational Safety, (2. Basım), Bursa: Dora Yayıncılık.

Yıldırım, E. Y. (2018). Cyber Attacks on Information Systems and Ensuring Cyber Security", *2.nd International Professional Science Symposium*, IVSS, pp.2.