Industry 4.0 Practices of Turkish Companies: A Qualitative Research

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Abstract

Whilst the Industry 4.0 concept emerges, practices and benefits of this new digital phenomenon is still vague for many enterprises and researchers. One of the most important reasons for this vagueness is that there is no strict consensus for the definition of the industry 4.0. As the concept can be defined as digitalization of production processes, thanks to the emerging technologies day by day, Industry 4.0 still may be confusing for many businesses and researchers. In the name of clarifying this vagueness, in this study, it has been aimed to investigate the practices of the industry 4.0 concept in the companies. "What kind of technologies are used for which activities in the companies under the industry 4.0 concept?" is the main question for this study. To answer this question companies which are listed as the "Top 500 hundred Industrial Enterprises" by the İstanbul Chamber of Industry have been investigated. After reviewing annual reports of these companies, it has been detected that 30 of them are dealing with Industry 4.0 concept as a strategy and/or application practice. In this study, results of this qualitative analysis will be presented to identify what kind of technological concepts are being used in the Turkish companies. According to the results, artificial intelligence and the robotic applications are the most popular Industry 4.0 technologies used in the reviewed companies.

Keywords
Industry 4.0, Digitalization, Smart Manufacturing, Industry 4.0 applications, ISO 500

1. Introduction
Since the Industry 4.0 term has been coined in 2011, many practitioners and academicians are challenging to define the concepts and principles of the phenomenon. As the Industry 4.0 concept is highly related with the technological developments, new technologies and infrastructures have the capacity of adding new definitions to the term. With all definitions, Industry 4.0 concept can be briefly described as digitalization of manufacturing and services (Elibal and Özceylan, 2020) via the technologies as shown in Figure-1.

According to Hoffman et al. (2018) the research community did not reach a unanimous consensus towards a definition of Industry 4.0 and several authors have raised concern over this lack of agreement. Kane et al. (2018) emphasized that one of the challenges of the fourth industrial revolution is to identify a common language, that makes it possible to find a common ground or at least a starting point for the discussions. Industry 4.0 is not so far adequately standardized, spread, and lacks the clear boundaries (Schuh et al. 2017). Despite the current discussion in research and practice, the different perceptions and characterizations of Industry 4.0 show that there is currently no clear definition (Schott et al., 2018). Stefan et al. (2018) declared that there are some number of concepts and technologies that are associated with Industry 4.0. Some of them are even used synonymously for the term Industry

4.0. These include, for example, the terms Cyber-Physical System, Cyber Physical Production System, Smart Factory or Internet of Things. However, it is hardly possible to distinguish these terms from each other as well as from the term Industry 4.0. This is due to the fact that all these terms have so far been ambiguously defined, which also applies to the term Industry 4.0.

According to the comments mentioned above it can be said that the only consensus about Industry 4.0 is there is no consensus on Industry 4.0 definition.
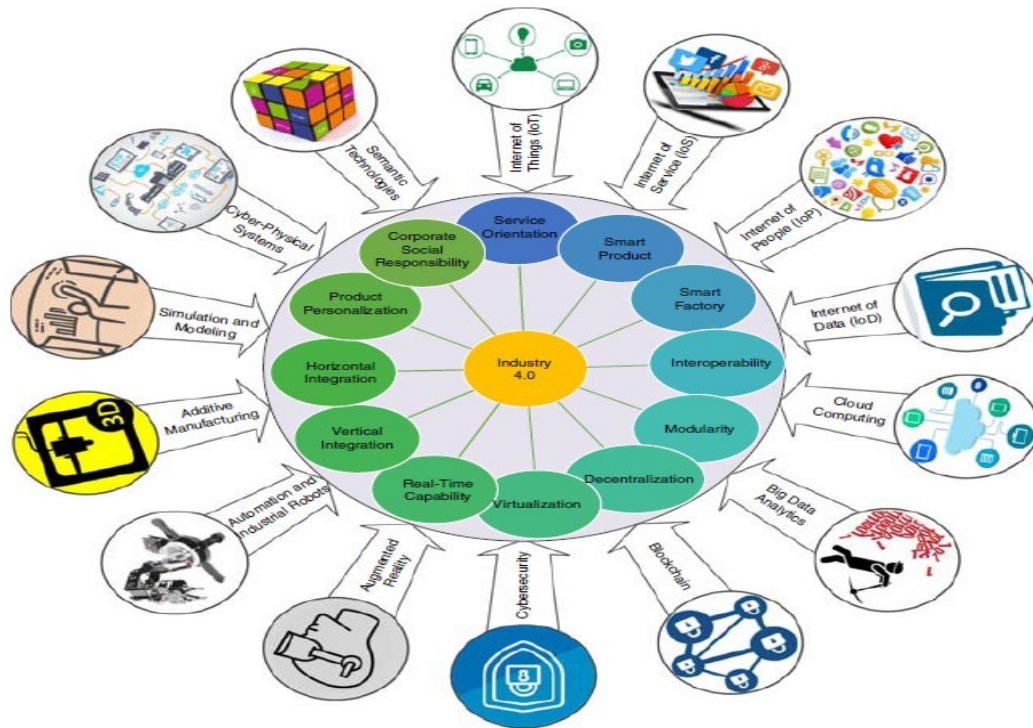

Figure 1. Design principles and technology trends of Industry 4.0. Ghobakhloo (2018)

With the aim of making an improvement of Industry 4.0 concept clarification, this paper tries to investigate real life practices rather than academic statements. "What kind of technologies are used for which activities in the companies under the industry 4.0 concept?" is the main question for this study. In other words, analyzing the key practices of companies in the frame of the 4ᵗʰ Industrial Revolution has been aimed to visualize the current situation of phenomenon. The aim of study is to clarify the industry 4.0 applications with real life stories rather than analyzing the situation of companies.

In the mean of making more clarification of the industry 4.0 implementations, ISO 500 companies in Turkey has been investigated and results presented in this study. Rather than the most developed countries, Turkey as a developing country has been chosen as a test bed and to identify the current situation. "Top 500 hundred Industrial Enterprises" (ISO 500) that has been declared by İstanbul Chamber of Industry has been aimed to investigate in this study. The structure of this study is as follows. In Section 2 literature review will be presented. Section 3 gives brief information about the methodology. Industry 4.0 applications of the selected companies will be presented in Section 4. In Section 5 results and discussions will be made and finally conclusion will be done.

2. Literature Review
A literature review has been conducted on Scopus Database with the search queries as in mentioned Table-1, until the date June 2022. Among 41 different publications, only three of them has been identified as investigating the applications in Turkish companies.

Table 1. Scopus Database search terms

Industry 4.0	practices	Turkey
	companies	
	ISO 500	
	applications	

Erkut et al. (2019) presented the industry 4.0 technologies usage rate among ISO 500 companies in Turkey. They collected data from Google search, via searching the company names and declared that 252 firms are related with Industry 4.0 technologies. According to their results, 3D printers, cloud, robots, radio frequency identification (RFID), sensors, simulation, augmented reality, big data, data analysis, artificial intelligence, cyber security and IoT are the used Industry 4.0 technologies. Data collection methodology is the handicap of this study. Authors claimed that the data is collected from the web search but no evidence for these data could be seen in the study.

Yıldırım and Demirbağ (2019) aimed to explore the current Industry 4.0 practices of Turkish white goods manufacturing companies through a case study. They conducted interviews, observation of the companies, investigating web sites and internet news of the companies and identified what kind of Industry 4.0 technologies are used. The limitation of the study is the investigation of only two companies which both are in the white goods industry.

Yüksel (2020) aimed to investigate Industry 4.0 applications in companies of Turkey. He also investigated the relation between the implementation level of Industry 4.0 with technological level of products manufactured, the presence of an R&D department, and the size of the company. This analysis has been done via a questionnaire that has been responded by 84 companies. According to the results of this paper, it has been concluded that cyber security is the most frequently Industry 4.0 application, while the augmented reality and artificial intelligence are the least. Internet of Things (IoT) is the most important application in the small sized companies while the big data and cyber security is the most important Industry 4.0 technologies implemented in middle sized companies and large companies, respectively. Even though the study gives information about the important and common applied technologies, the application fields are still not declared in the study.

The limitations of the reviewed literature are the motivation of this paper. All of the three reviewed publications do not include brief or detailed case practices about Industry 4.0 implementation of Turkish companies. Data collection methodology is the limitation of the first study. Second study gives slightly information about the technologies and the processes but only limited for one sector and two companies.

3. Methodology

As in mentioned in Section 1, the aim of this paper is to investigate the ISO 500 firms in Turkey. Thus, first the list of top 500 hundred companies of Turkey which has been declared by the Istanbul Chamber of commerce been extracted (ISO 500). Figure 2 shows the steps of the methodology.
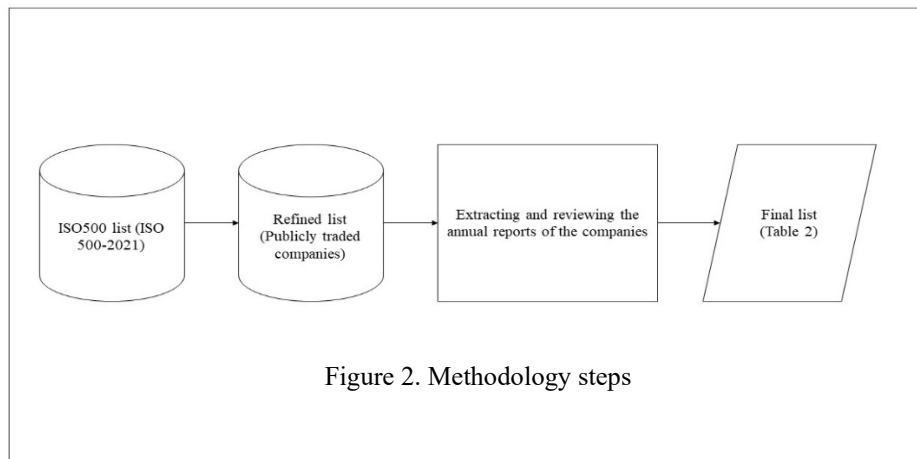

Figure 2. Methodology steps

Among 500 hundred companies 63 publicly traded companies has been selected to be investigated. The reason for the selection of publicly traded companies is that annual reports are regularly published in the investor relations section of the websites of these companies. In this study, the existence of Industry 4.0 applications will be scanned in the annual reports of the companies. After reviewing the annual reports, among 63 companies, it has been seen that 30 of them declares their Industry 4.0 engagements in their organization, as in shown in Table 2.

Table 2. Company list

Company No	Company Name	ISO 500 Rank
C1	TÜPRAŞ-Türkiye Petrol Rafinerileri A.Ş.	1
C2	Ford Otomotiv Sanayi A.Ş.	2
C3	İskenderun Demir ve Çelik A.Ş.	5
C4	Ereğli Demir ve Çelik Fabrikaları T.A.Ş.	7
C5	Arçelik A.Ş.	8
C6	TOFAŞ Türk Otomobil Fabrikası A.Ş.	10
C7	PETKİM Petrokimya Holding A.Ş.	15
C8	Aselsan Elektronik San. ve Tic. A.Ş.	17
C9	Vestel Beyaz Eşya San. ve Tic. A.Ş.	18
C10	Türkiye Şişe ve Cam Fabrikaları A.Ş.	22
C11	KARDEMİR Karabük Demir Çelik San. ve Tic. A.Ş.	24
C12	Vestel Elektronik San. ve Tic. A.Ş.	26
C13	Aygaz A.Ş.	33
C14	Türk Traktör ve Ziraat Makineleri A.Ş.	38
C15	AKSA Akrilik Kimya Sanayii A.Ş.	42
C16	BRİSA Bridgestone Sabancı Lastik San. ve Tic. A.Ş.	60
C17	Coca-Cola İçecek A.Ş.	63
C18	OYAK Çimento Fabrikaları A.Ş.	91
C19	Otokar Otomotiv ve Savunma Sanayi A.Ş.	122
C20	Pınar Süt Mamülleri Sanayii A.Ş.	156
C21	Çimsa Çimento San. ve Tic. A.Ş.	158
C22	Akçansa Çimento San. ve Tic. A.Ş.	175
C23	Anadolu Isuzu Otomotiv San. ve Tic. A.Ş.	196
C24	YATAŞ Yatak ve Yorgan San. Tic. A.Ş.	232
C25	Nuh Çimento Sanayi A.Ş.	268
C26	Menderes Tekstil San. ve Tic. A.Ş.	310
C27	Hektaş Ticaret T.A.Ş.	341
C28	Doğanlar Mobilya Grubu İmalat San. ve Tic. A.Ş.	365
C29	Tat Gıda Sanayi A.Ş.	414
C30	Kervan Gıda San. ve Tic. A.Ş.	429

4. Industry 4.0 Applications of the Selected Companies

In this section Industry 4.0 applications of the companies which are mentioned in Table 2 have been presented. These conclusions have been done according to the declarations in the annual reports of the companies.

Company C1, which is the biggest company in Turkey in the name of annual turnover, has many applications and project under the concept of Industry 4.0 and some of them can be summarized as follows (Tüpraş);

- Robotic systems
- Big data analytics via artificial intelligence to estimate and optimize the energy consumption.
- Wearable technologies with Internet of Things (IoT) to be used in hazardous production areas.
- Data driven decision systems.

Company C2 states that it has gathered his digital transformation efforts in five groups, covering the entire value chain, including dealers, customers, suppliers, employees, product design and production. Some of the main focus areas of the company in the frame of Industry 4.0 can be summarized as follows (Ford);

- Artificial intelligence-based chat robot used in human resources activities.
- Automated advanced production planning system
- M2M communication
- Blockchain technologies used in supplier management
- Automated procurement management
- Data driven decision systems

C4 and his subsidiary company C3, who has just started his digital transformation journey aims to collect and analyze big data, proceeds his digital transformation process with constructing a "data lake" that all shareholders can access in a democratic way. Mobile applications both for customers and the internal stakeholders, digital MES and automated budget planning activities are planned as the first implementations of the industry 4.0 concept (İsdemir, Erdemir).

C5 shapes his Industry 4.0 transformation by focusing on "Customer", "Products and Services", "Process and Systems" and "People and Organization" (Arçelik).
The focus areas of this transformation have been determined as follows:

- Creating and using digital products on a global scale
- Disseminating digital process management practices and increasing employee efficiency,
- Developing modular product management applications and disseminating industry 4.0 applications,
- Providing harmonization and standardization in digital applications all over the world,
- Data-based business management supported by data analytics and artificial intelligence,
- Device-independent, secure, sustainable infrastructure and operation management,
- Incorporating future-oriented new technologies through open innovation.

C6, which is one of the leading automotive companies in Turkey has conducted some Industry 4.0 projects as follows (Tofaş);

- Much equipment used in production are connected to the Internet of Things (IoT) platforms that enables instant monitoring of the critical parameters of the equipment.
- Using robotic process automation (RPA) technology, projects that offer solutions for repetitive and attention-demanding operations performed by employees were implemented.
- Critical quality control processes are guaranteed with the projects realized using new generation image processing and machine vision technologies.
- Implementation of collaborative robots in some operations that require the robot and employees to work together.
- Improvements were achieved in labor costs and ergonomics with the projects carried out on wearable technologies.
- With different projects related to data science, artificial intelligence and machine learning technologies, efficiency has been increased, especially by optimizing man-made processes. These technologies have also provided significant opportunities and improvements in the field of occupational safety.

C7 uses artificial intelligence applications in production and maintenance departments. Augmented reality is another Industry 4.0 technology which is used in the company especially in maintenance operations. Decisions systems which use big data and artificial intelligence, machine learning driven estimation and optimization systems are also used in the company (Petkim).

C8 continues his research and studies to improve the way of doing business by using technologies such as digital twin, internet of things, big data, deep learning in projects such as PLM, ERP and CRM. The focal point of the company in its digitalization journey has been determined as PLM (Aselsan).

C12 and his subsidiary company C9 are the important applicators of Industry 4.0 concepts in Turkey. Artificial intelligence software for horizontal-vertical value chain integration, Internet of Things (IoT) technologies, smart automation, Automated Guided Vehicle (AGV) and Autonomous Mobile Robots (AMR) applications has been indicated as the major Industry 4.0 applications which are implemented in the company. Some Industry 4.0 applications of the companies are summarized as (Vesbe, Vestel);

- Manufacturing Execution System (MES): The company declares that manufacturing traceability can be done via MES. Also, it is aimed to develop an accurate, fast, error-free, loss-free and lean production system that reduces human intervention by optimizing, automatic installation and error estimation with MES.
- Machine to Machine Connectivity (M2M): With M2M, a lot of data is collected with the aim of performing performance analysis, quality, material and order tracking on production lines. The collected data is analyzed and can be reported with web-based instant tracking. In addition, it has been stated that material losses are largely prevented by including production planning and material consumption data in the M2M system. Also, it is aimed to develop prediction and suggestion applications by adding machine learning and artificial intelligence algorithms to the M2M system.
- Smart Maintenance: In the concept of smart maintenance, the company evaluates many data including working values, production details of the machine, maintenance information and working conditions obtained from the machines used in the production processes with machine learning and data analysis methods. Predictive maintenance which executed with artificial intelligence techniques are another smart maintenance application of the company.
- Virtual and Augmented Reality: The company aims to train operators quickly and easily and to increase production quality via the virtual reality and augmented reality technologies. Before all investment decisions (robots, machinery-equipment-automatic warehouses, etc.), it is ensured that the targets are attainable financially and technically with virtual reality programs and special simulations. In addition, it is planned to transfer the correct information to all new employees with augmented and/or virtual reality by systematically recording the usage information of all machines used in production.
- 3D Printing
- Automated Guided Vehicle (AGV) and Autonomous Mobile Robots (AMR)

C10 started his digital transformation journey in 2016 and since then many digital transformation projects have been handled. Some of them are summarized as below (Şişecam);
- Digital twins of the factories
- Big data architecture
- Big data analytics
- Digital supply chain applications
- Digital financial operations such as fraud detection
- RFID and IoT applications in the production area
- Robotic applications

In C11, the project called "S/4 HANA", was commissioned to ensure the production traceability throughout the company. With the S/4 HANA project, not only the production traceability but also the R&D projects were tracked in SAP; besides, management reports, performance evaluation system, customer relations, career and training systems were implemented into the system (Kardemir).

By using advanced technologies and data analytics, C13 has accomplished digital projects with high added value goals such as customer satisfaction, process optimizations and efficiency, and business model transformation. One

of these projects is called as Aygaz E-Commerce Transformation Project that aims to renewal of all digital channels such as mobile application, website, VR, Chatbot. Robotic process automation projects, artificial intelligence applications using big data and IoT platform in sales, production, supply processes are among the other Industry 4.0 implementations of the company (Aygaz).

C14 developed a mobile application which farmers can reach agricultural information that can assist their decisions. Virtual reality applications are another Industry 4.0 concept which used by the company. Employees are given the opportunity to practice in the virtual workshop created in the digital environment, after the operation training, they practice in the "Virtual Reality Training Laboratories". In this way, it is aimed to minimize the possibility of mistakes that can be made during the production phase, to prevent work accidents, to reduce scrap costs, and to prevent quality problems at the same time, by experiencing the possible mistakes that the technical personnel may make in the physical environment beforehand (Türktraktör).

C15 uses robotic process automation (RPA), which allows their employees to focus on more value-added works by reducing the error rate in the works and facilitating the work transfer processes between employees. This system has been actively used in 10 processes in the finance, accounting and purchasing departments. Also, the company aims to save time in their business and accelerate decision-making processes with the business intelligence application, which can quickly analyze the data in different sources and turn it into a visual report (Aksa).

C16 indicated that wearable technological solutions such as smart googles, smart gloves are used in the company. Also, an artificial intelligence-based procurement system is used in the company (Brisa).

C17 declares that in order to reach higher levels of optimization and efficiency, basic building block solutions such as Enterprise Resource Planning, Customer Relationship Management, Contract Management, Purchasing Management, Warehouse Management and Shipping Management and increment of automation systems has been established. Via combining cloud computing, artificial intelligence/machine learning systems (such as dialog-based artificial intelligence, image processing, deep neural networks), IoT, edge computing and robotic process automation capabilities, the digital twin of the organization, production lines and customer experience has been created. Some example Industry 4.0 applications of the company are (CocaCola);
- Route planning algorithm
- Image processing
- Digital twin of the production processes

C18 is conducting a project called "Oyak 4.0". The company declares that the focus of this project is the big data. Via integrating all production facilities which are at different locations, all production data is collected and visualized. With the constantly increasing data volume, a detailed and deep analysis system has been developed to benefit more from these data. With the "Automatic Machine Learning" (Auto-ML) implementation, all data is analyzed, and the high consistency models obtained allow instant predictions to be carried out on the data that is flowing. In this way, instant anomalies are detected, warnings and corrective measures are triggered, early actions are provided by presenting forecasts for the future, decision-making and implementation stages in cement production from planning to operation are supported by artificial intelligence (Oyak).

C19 has developed a machine learning algorithm that evaluates work orders with forklift locations and characteristics that assigns work to the most suitable forklift with the shortest route. Another machine learning algorithm which calculates that predicts which supplier will not be able to provide timely supply in the future by analyzing the historical data of the suppliers. Quality predictions of welding with machine learning algorithm, automatic trajectory extraction in robotic systems are other projects of the company in the concept of Industry 4.0 applications (Otokar).

As a part of his Industry 4.0 transformation process, C20 implemented robotic palletizing automation systems in his production facilities. Systems that ensure continuous monitoring of sales and distribution operations are among the company's other Industry 4.0 applications (Pınarsüt).

C21 has been started the digitalization journey by developing a model in which both sales and operation units can deliver their work demands to the R&D Center. The company also launched the "Chatbot" application, which receives online sales and technical support requests within the scope of digitalization, in the aim of increasing the

number of customer communication channels. Another important project of the company within the scope of Industry 4.0 is the digitization of the production line which aims increasing efficiency and product quality, as well as optimizing the use of natural resources and reducing environmental impact (Çimsa).

IoT, process automation and optimization systems, dynamic simulation is the major Industry 4.0 applications in C22. The company declares that all quality control parameters are automatically transferred into the system. Via the continuous quality control production can be controlled digitally (Akçansa).

MES equipped with IoT is the major Industry 4.0 application in C23. Besides MES, advanced planning and optimization system via artificial intelligence assistance, automated warehouse projects, robotic process automation, AGVs, online spare part platform are other important Industry 4.0 implementations in the company (Aisuzu).

In C24, the "360 Degree Virtual Tour" program, in which all visible indoor and outdoor spaces and activities are watched interactively on computers and the internet, was added to the website of the company which allows consumers to shop "as if they were in a store" without going to the store. Algorithms to increase sales such as purchased together, complementary products, favorite products and viewed together were put into use. Via artificial intelligence, the company has begun to identify people's preferences, tastes and habits faster and more efficiently. Furthermore, the company plans to use augmented reality applications that will allow customers to create personalized orders. In addition, it is planned to use artificial intelligence in online sales like a store staff, and in cases where artificial intelligence cannot respond, it is planned to make a human touch to e-commerce and connect online customers to the architects and store personnel in the stores (Yataş).

The most important digitalization activities in C25 are automation systems placed at various stages of production, database, quality management systems followed by the establishment of fiber infrastructures, document management system, dealer, and intranet portals. The company indicates that sales processes started to take place in a more controlled and faster manner with the renewed automation systems, and customers were able to access their data online more quickly thanks to the dealer customer portal. Also, the PLC (Programmable Logic Controller) Programmable Controller systems which are used in gas analysis systems, weighing systems and raw material analysis systems are another Industry 4.0 technologies that are implemented in the company (Nuh).

C26 uses automated guided vehichles (AGVs) and robotic packaging systems in the production. Also, they plan to use automated image processing systems in the production line with IoT systems. Not only in production but also in management systems are used in the company such as digital audit sytems (Menderes).

C27 developed a mobile "smart assistant" application which has been equipped with modules such as field/land satellite images, plant health status, current stock market and market prices according to the current needs of the farmers (Hektaş).

C28 plans to use algorithms and systems which will allow customers to create specialized preferences and create a "smart shopping" concept (Doğtaş).

C29 stands out in its "digital agriculture" activities. The company offers different digital solutions from data collection to interpretation, from mechanization to remote monitoring; first with pilot projects and then with dissemination projects. By using these digital technologies, a technological infrastructure and tracking system was created to establish a relationship between field data and product performance, and practices that produce solutions for increasing communication with farmers and supporting the development of farmers were implemented. Some Industry 4.0 technologies applied in the frame of digital agriculture by the company are (Tat);

- Satellite imaging: Projects are carried out to collect data such as soil structure, temperature, humidity and conductivity that affect plant growth from soil and air on a field basis, and to establish a cause-effect relationship with field observations.
- Sensor-assisted automatic irrigation system.
- Hoeing machine automatic steering system.
- Imaging with drone.

- Agricultural climate stations and early warning systems: The company can forecast the weather conditions on a local basis through its four agro-climate monitoring stations and can conduct risk analysis of diseases that may affect tomato growth.
- Digital pheromone trap systems: It is a system where tomato pests are tracked and changes in the population can be analyzed via remote access without going to the field. In this system, an attractive odor is released to field pests with biological pheromones placed in certain parts of the field, and the number of creatures trapped by this odor is monitored by automatic camera systems.
- Soil analysis
- Tomato plantation area estimation and harvest projection.
- Irrigation recommendation system based on satellite tracking.

C30 declares that they are conducting a project "In-Line Process Monitoring and Digitalization in Production" that aims to automate some manual operations such as packaging and quality control (Kervan).

5. Results and Discussion

As in mentioned in Section 3, Industry 4.0 applications of the 30 Turkish companies has been investigated according to the information in their published annual reports. Gathered information have been reviewed and the used technologies have been summarized as in Table 3.

It should be remembered that the conclusions about Industry 4.0 applications and technologies have been done according to the declarations in the annual reports, which means there is a possibility that all applications and technologies may not be mentioned in the reports. Companies may indicate the important aspects of their Industry 4.0 transformation, so the results may include missing information.

Even though this study does not claim that results cover everything and the possibility of missing information, still Table 3 gives some important results about the industry 4.0 technologies used in the reviewed companies. According to the Table 3, artificial intelligence and the robotics are the most popular applications, respectively. IoT, big data analytics and machine learning are the next common technologies used. Whilst it is a new technology, augmented reality is also having a considerable usage in the reviewed companies.

Table 3. Industry 4.0 technologies used in the companies

Company No	Robotic Systems	Big Data Analytics	Artificial Intelligence	Machine Learning	Weareble Technologies	M2M	Sensor	RFID	IoT	Blockchain	Mobile Applications	MES	ERP	Augmented/Virtual Reality	3D Printing	AGV	Image Processing	Digital Twin	Web Portal	Customer Applications	Cloud
C1	x	x	x		x																
C2			x			x				x											
C3-C4		x									x	x									
C5		x	x																		
C6	x		x	x	x				x								x				
C7			x	x										x							
C8		x							x									x			
C9-C12	x		x	x		x					x			x	x	x					
C10	x	x						x	x									x			

Company No	Robotic Systems	Big Data Analytics	Artificial Intelligence	Machine Learning	Weareble Technologies	M2M	Sensor	RFID	IoT	Blockchain	Mobile Applications	MES	ERP	Augmented/Virtual Reality	3D Printing	AGV	Image Processing	Digital Twin	Web Portal	Customer Applications	Cloud
C11													x								
C13	x		x						x		x										
C14											x			x							
C15	x																				
C16			x		x																
C17			x	x													x	x			x
C18		x	x																		
C19	x			x																	
C20	x																				
C21																				x	
C22									x												
C23	x		x						x			x				x					
C24			x											x							
C25																			x		
C27											x										
C29	x						x										x				
C30	x																				

6. Conclusion

In this study 30 Turkish companies which are selected from the "Top 500 hundred Industrial Enterprises" list, that has been published by İstanbul Chamber of Industry, has been reviewed to clarify what kind of Industry 4.0 technologies are used in the companies. The aim of study is to clarify the industry 4.0 applications with real life stories rather than analyzing the situation of companies.

Results showed us artificial intelligence and the robotic applications are the common Industry 4.0 applications.

Results that are mentioned in Section 4 should not be generalized to all Turkish companies. The possibility of not covering all the industry 4.0 aspects in the reviewed companies is the main limitation of this study, so as future research, this study may be expanded with other techniques such as interviews and questionnaires which can be conducted to the reviewed companies.

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Biography

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