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Awareness and readiness of Industry 4.0: The case of Turkish manufacturing industry

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A B S T R A C T

The concept Industry 4.0 (I4.0) represents intelligent production processes combining cyber and physical systems through a set of technologies such as internet of things, big data and cloud computing. Transition to Industry 4.0 is expected to cause formidable structural changes, productivity increments and competitiveness in manufacturing industry in all over the world. This study aimed to investigate the general approach to the concept of Industry 4.0 and levels of adoption of the basic Industry 4.0 technologies in manufacturing firms across Turkey. For this purpose, a survey was conducted with 427 firms with various sizes (micro, small, medium and large) operating in six sub-sectors (automotive; electronic; machinery; chemical; food; and textile) of Turkish manufacturing. The paper examined nine I4.0 technologies: autonomous robots, big data applications, cloud computing, cyber security, simulation approaches, additive manufacturing, system integration, internet of things, and augmented reality. The results revealed that, there is a significant correlation between the degrees of importance and implementation of the basic Industry 4.0 technologies. Moreover, I4.0 implementation degree increases as the firm size increases. The top three industries in Turkish manufacturing that use the most basic Industry 4.0 technologies are automotive industry, electrical and electronics, and machinery, respectively. The analyses are aimed to achieve a better understanding of the concept Industry 4.0 by comparing different groups of manufacturers.

A R T I C L E I N F O

Keywords:
Industry 4.0;
Additive manufacturing;
Autonomous robots;
Cloud technologies;
Cyber security;
Internet of things (IoT);
Big data;
Augmented reality

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1. Introduction

Industry 4.0 (I4.0) defines a new technological era (i.e. the intelligent factory system that combines embedded system manufacturing technologies and intelligent production processes) that will change the industrial and production processes [1], while providing production ecosystems produced by intelligent systems with autonomous features such as self-structuring, self-monitoring and self-healing [2]. Integration of these systems creates an intelligent manufacturing environment which yields higher productivity and faster production of customized and high-quality products. The main idea in here is to capture a competitive industrial advantage with the help of the state of art technologies. This concept not only changes the dynamics of competition between the nations and the companies in the business world, but also reshapes the way of doing business and setting strategies for the future. Just like other industrial revolutions, The 4th Industrial Revolution is a process that requires structural changes, new business models, destructive innovations and paradigm shifts from centrally controlled to decentralized production processes [3, 4]. Another aspect of Industry 4.0 is its potential to contribute to the sustainability of future supply chains with optimum use of resources [5].

The concept of Industry 4.0 was first used in 2011 at the Hannover Fair in Germany [6]. Then it was developed to create a national policy by The German Government and dispersed to other countries in the world under the label of The 4th Industrial Revolution. Strategic initiatives of many countries around the world aim to catch the benefits offered by this new digital era. However, the structure of the manufacturing industry of each country and their advancement in production technologies differ. For this reason, some indices are needed to measure the compliance of countries with industry 4.0. The Roland Berger Readiness Index, defines four Industry 4.0 readiness categories for European countries: (1) Frontrunners with high manufacturing share and high readiness: Germany, Sweden and Austria; (2) Potentialists with low manufacturing share and high readiness: Belgium, Finland, UK, France, Netherlands; (3) Traditionalists with high manufacturing share and low readiness: Slovenia, Slovakia, Czech Republic, Hungary and Lithuania; (4) Hesitators with low manufacturing share and low readiness: Portugal, Greece, Poland, Bulgaria, Italy, Spain and Turkey [7]. Although Turkey seems to be one of the hesitators with low digitalization level in between European Countries, TUSIAD (Turkish Industry and Business Association)'s industry report reveals the potential of Turkish manufacturing industry for Industry 4.0 transformation.

The purpose of this study is to investigate the approaches and readiness of Turkish manufacturing firms to Industry 4.0 by using self-assessment tools. For this purpose, a survey was conducted with firms operating in six different sub-sectors of Turkish manufacturing. The outline of the article is designed as follows: The next section gives theoretical background of the term Industry 4.0 and the key technologies it covers. The third section presents a comprehensive review of the existing literature on Industry 4.0 including articles and reports. Fourth section presents the methodology of data collection, and the descriptive statistics. Section five presents the basic findings of the survey and the results of the analysis while section six presents concluding remarks of this study and discusses future studies.

2. Theoretical background of Industry 4.0

The number of studies on industry 4.0 is increasing since it was first introduced in 2011, and yet there is no single common definition of industry 4.0. Based on the common points of the definitions, industry 4.0 can be defined as the production systems that production is made by smart and autonomous machines that can communicate and coordinate with each other [9].

In the new era of digitalization, companies are expected to face a new dynamic environment focused on machine learning and real time data processing. Firms will be able to accelerate their data collection and analysis methods through flexible production process. They would produce higher quality products with lower costs and hence increase their efficiency with the opportunities offered by Industry 4.0.

In literature, Industry 4.0 encompasses nine technologies which are big data and analytics, autonomous robots, simulation, horizontal and vertical system integration, the internet of things, cybersecurity, the cloud, additive manufacturing, and augmented reality [10]. The classifications of key technologies of Industry 4.0 and the brief descriptions of each technique are as follows:

Big data and analytics: Large-scale datasets are a combination of large, complex, diverse and heterogeneous data generated from a variety of sources, such as click flows, sensors, video sharing, business processes, and social networks [11]. Data and data analytics are critical in digital and smart factories emerging with Industry 4.0. Therefore, data from many different sources need to be collected, classified, evaluated and made available for decision-making in real time.

Autonomous robots: The organizational structure that promotes human-robot collaboration in the production process is emphasized. Robots will interact with each other in this structure via internet. These collaborative robots (Cobots) will not only work closely with other robots, but also humans and learn from them for better practices [12].

Simulation: The physical production processes in factories can be reflected by a virtual environment with the help of simulation technologies. For example, quality improvement in functions such as testing, setup and installation can be performed in virtual environments. In addition to quality enhancement, cost savings can be achieved by decreasing setup and maintenance times with simulation technologies.

Horizontal and vertical system integration: Companies, departments, functions and capabilities will become more consistent with Industry 4.0, and cross-company and universal data integration networks will evolve to autonomous value chains. Horizontal integration allows firms to create, an effective ecosystem to share information, financial resources and materials, while vertical integration enables them to obtain flexible and restructured production systems [12].

The internet of things (IoT): "The IoT refers to an inter-networking world in which various objects embedded to electronic sensors, actuators or other digital devices where they can connect to each other and exchange the data they collected" [14, 15]. IoT technologies can be used for automation of various operations such as remote controlling, machining, lighting and heating. Furthermore, decision making is decentralized by machine to machine (M2M) interactions via internet of things.

Cybersecurity: Perhaps one of the most discussed negative aspects of digitalization is the issue of cyber security. Users of Industry 4.0 technologies will not only face the traditional cyber security challenges, but also the unique security and privacy challenges inherent in the digital Industry [2]. The mechanization of production processes and internet-based interaction and communication between machines increase the need for security especially in the critical industrial systems. Therefore, secure and reliable systems are vital for sustainability in Industry 4.0.

The cloud: Due to data-based production systems, the amount of data produced increases and effective management and storage of this data becomes important. Unlike the traditional storage services, cloud technologies provide storage space in a smaller area for a large amount of data from various sources [16, 17]. "Machine data and functionality will be deployed to the cloud, enabling more data-driven services for production systems" [10].

Additive manufacturing: Additive manufacturing technologies are the technologies that enable a model to be produced by means of three-dimensional computer aided design systems without the need of any process planning [18]. The system receives the information needed from a computer-aided design (CAD) program [19]. This technology facilitates the production of products with complex production processes.

Augmented reality: "Augmented reality (AR) can be defined as a computer graphics technique where virtual symbols are superimposed to a real image of the external world" [20]. Augmented reality technologies ease daily lives of the users by providing information about objects [21].

3. Literature review

The literature on the readiness and preparedness to Industry 4.0 is increasing with different types of publications. Our review on the current literature includes both academic papers and industry reports is given in Table 1.

Table 1 Literature review on Industry 4.0

Author	Topic/Aim is	Method	Results
Ratnasingam *et al.* (2019) [22]	to measure Industry 4.0 readiness of the firms operating in the furniture sector in Malaysia.	Survey method	- Machining centres and finishing processes are the processes requiring the most technological infrastructure - Driving forces on the way to digitalization are higher production capacity, cost, product characteristics and government policy. - The sector is not yet ready for Industry 4.0
Machadoa *et al.* (2019) [23]	to appraise the readiness of seven companies on the digitalization	Survey and case study	- Firms are at the beginning of the Industry 4.0 process. - One of the biggest obstacles related to Industry 4.0 is stated as lack of knowledge
Schumacher *et al.* (2019) [24]	to present a model to manufacturing companies related to Industry 4.0	Model design	- Model consists of 65 critical success factors to assess maturity, and roadmaps with 10-step. - The model was applied on manufacturing companies in Hungary, Austria, Germany, China, Slovakia and India.

Table 1 (continuation)

Pacchini *et al.* (2019) [25]	to propose a model of readiness of a manufacturing companies for Industry 4	Model design	- The model covers Industry 4.0 principles and technologies. - This model was implemented in auto-parts manufacturing company in Brazil. - The model provides information about the challenges in the transition to I4.0 to managers, and contributes to both theory and practice.
Castro *et al.* (2019) [26]	to present a model for self-assessment on the i4.0 readiness	Model design	- This model covers six dimensions: smart factory, data-driven services, smart operations, strategy and organization, smart products and human resources. - The result of this study shows that how a company can make better Industry 4.0 readiness level by using SHIFTo4.0.
Stentoft *et al.* (2019) [27]	to measure digitalization readiness level of small and medium-sized manufacturers	Survey method	- Danish SMEs have a low to moderate Industry 4.0 preparation. - Incentive implementations cause an in-crease in Industry 4.0 readiness
Castelo-Branco *et al.* (2019) [3]	to measure factors and the degree of adoption of Industry 4.0	Factor and cluster analyses	- There is a large distribution between countries in required conditions for that readiness.
Nick *et al* (2019) [28]	to search Industry 4.0 approaches in some countries such as Germany, Austria and Hungary	Model design	- This results help to capture the different phases of digitization and Industry 4.0 in these countries - This study defined objectives, strategies and also solutions for Industry 4.0 related problems
Medic *et al.* (2019) [29]	to evaluate the usage of advanced manufacturing technologies in Serbia	FAHP and PROMETHEE model	- The results show that, digital data sharing among supply chain members, production planning and production control systems are important issues in the context of I4.0 implementation.
Resman *et al.* (2019) [30]	to propose a new model based on I4.0 technologies for smart factory planning	Model design	- The proposed model is easy to use and offers a more reliable and simple modelling of smart factory compared to reference architectural model of I4.0.
Mittal *et al.* (2018) [31]	to analyse available systems and Industry 4.0 maturity models	Model design	- This study provides information to help improvement of realistic smart manufacturing.
Vieira *et al.* (2018) [32]	to introduce a R&D agenda for discrete-even simulation (DES) in the context of I4.0	Literature review	- The significant DES characteristics are: automation of data exchange, automatically generated simulation models and visualization.
Kusiak (2018) [33]	to provide a theoretical framework of smart manufacturing	Theoretical study	- Manufacturing technology, sustainability, networking, data analysis, material science and predictive engineering are the essential issues of smart manufacturing.
Basl (2017) [34]	to analyse the level of knowledge of firms and employees about I4.0.	Survey method	- 40 % of companies deal with Industry 4.0 for more than one year. - 75 % of companies says that their main reason for not implementing Industry 4.0 is low awareness of the topic.
Deloitte report (2017) [35]	to evaluate Industry 4.0 readiness.	Survey method	- Public institutions will be more effective in shaping society, the greatest impact on companies is to deliver the best possible product / service to customers, two most talked topics in the past year is to develop / create new products and services and improve productivity, technological initiatives are mostly in operations / processes.
Berger report (2017) [7]	to determine the advantages and disadvantages of Turkish food and beverage Industry in terms of Industry 4.0.	Survey method	- Although Turkey has the positive position in rankings, it is in the low country group in the readiness of Industry 4.0. - There are advisory steps as to how Turkey can ensure and improve readiness of Industry 4.0.
Europarl report (2016) [36]	to introduce related issues with Industry 4.0 such as its challenges and technologies.	SWOT analysis	- The supporting policies of the European Union for Industry 4.0; cyber security risks; and technological, social and business changes were discussed. - New policy proposals were presented.
TUSIAD report (2016) [8]	to analyse the opportunities emerging from Industry 4.0 and to demonstrate the potential of Turkish manufacturing Industry.	Survey method	- It was observed that some concrete steps have already taken for Industry 4.0 in Turkey. - It is sated that there is high-level of awareness and interest in the Industry to benefit from Industry 4.0 technologies and create competitive advantage in Turkey.
Infosys report (2015) [37]	to find out what the companies' plans for the technology journey are.	Survey method	- Although the majority of the companies are aware of the potential power of the Industry 4.0 technologies, only a few of them use these concepts in practice. - China is in a leading position compared to other countries. - The process Industry is the leader to the other industries.

4. Research method and sample description

This study tries to find out the readiness of Turkish manufacturing companies to the new digital era by examining the implementation degrees of basic Industry 4.0 principles in their businesses. The sampling manufacturers were drawn from the database of "The Union of Chambers and Commodity Exchanges of Turkey". The data was collected through a survey conducted by phone interviews. The data includes 427 observations (respondent firms) from six different manufacturing sectors. Sampling universe is determined as 600 firms at the beginning of the study, and we were able to have response from about 70 % of these firms. The sample industries are chosen in accordance with the Industry 4.0 report of TUSIAD, (2016) [8]. The sub-industries included in the study are electrical and electronic products, machinery, food and beverage, chemical, automotive, and textile manufacturing industries. Table 2 summarizes the distribution of these firms by industries.

The distribution of respondent firms by size is given in the Table 3. The sample includes micro, small, medium and large firms. The basic distinction between various size segments is based on SMEs (small and medium-sized enterprises) definition of EU (European Union) and Turkey. According to its definition, SMEs are examined mainly in three categories which are micro, small and medium-sized enterprises with personnel numbers "1-9", "10-49", "50-249" respectively [38, 39]. Since this study is aimed to investigate companies in all sizes, the segment of large firms having employees more than 250 is also included. In order to be able to make accurate comparisons, the composition of the firms in the sample universe was chosen homogenously.

According to Table 4 which indicates the respondent's position in the company, the great majority of the firms (252 firms) are represented by a "production manager" with the ratio of 59.3 %. The titles following "production manager" are general manager (20 %), company owner (6.1 %) and R&D manager (4.2 %), respectively.

SPSS 22.0 software package is used to analyse the data collected via survey.

Table 2 Distribution of firms by sector

Industries	Number of firms	Ratio
Electrical and Electronic Products Manufacturing	71	16.7
General and Special Purpose Machinery	70	16.5
Food and Beverage Manufacturing	71	16.7
Chemical Manufacturing	75	17.6
Automotive Manufacturing	68	16.0
Textile / Clothing Manufacturing	70	16.5
Total	425	100.0

Table 3 Distribution of firms by size

Size	Number of employees	Number of firms	Ratio
Micro	1-9	106	24.9
Small	10-49	107	25.2
Medium	50-249	107	25.2
Large	250 and more	105	24.7
Total		425	100.0

Table 4 Respondent's title in the firm

Respondent's title	Number of firms	Ratio
Production Manager	252	59.3
General Manager / Business Manager / General Coordinator	85	20.0
Owner / Partner	26	6.1
R & D Manager	18	4.2
Production Planning Manager	17	4.0
Quality Manager	11	2.6
Technology Manager	7	1.6
Factory Manager	5	1.2
Assistant General Manager	3	0.7
Other	1	0.2
Total	425	100.0

5. Results and discussion

The questions covered in the survey are aimed to understand the readiness of respondent firms for Industry 4.0 and the degree of implementation of basic Industry 4.0 concepts into their businesses. The first question of the survey is aimed to find out approaches of the firms towards the Industry 4.0 and it is adapted from the study of Basl [34]. Table 5 gives the respondents' answers. According to Table 5, although the great majority of the firms heard about the term Industry 4.0 with the ratio of 80.7 %, only 15.3 % (corresponds to 65 firms) of them are dealing with it for more than 1 year. By combining the new implementers, we can conclude that the total of 26.8 % firms are implementing the concepts of Industry 4.0. While 21.2 % of the companies admitted that they have not enough knowledge related to the concept of Industry 4.0, 32.7 % of them haven't considered its implementation due to various reasons.

Considering the approaches of the firms to Industry 4.0 technologies by sub-sectors, it can be concluded that the automotive manufacturing industry is the leader in implementing Industry 4.0 principles as expected. Together with the new implementers and long term users, a total of 35.3 % of the firms operating in automotive manufacturing industry have adopted Industry 4.0 principles into their business operations. Indeed, the automotive industry is expected to yield better results compared to the other industries, because it experiences the best practices of Industry 4.0. Following automotive industry, electrical and electronic and machinery manufacturing industries are the second and third industries with the highest ratio of the firms implementing Industry 4.0 practices. While 20.8 % of chemical manufacturers have adopted Industry 4.0 technologies, the ratios tend to decrease in textile and clothing (14.2 %) and food and beverage (12.8 %) industries. Data reveals that the great majority of the firms in textile and clothing industry have not heard about the term Industry 4.0. The ratio in this industry is twice as much as the average of all covered industries. The food and beverage industry has the highest ratio (34.3 %) among the companies who have heard the term Industry 4.0, but have no idea what exactly it covers. It can be said that both of these sectors need to be well informed about this new industry revolution and its content.

The summary of the distribution of the approaches to Industry 4.0 technologies by the size of the firms are given in the Table 6. According to Table 6, there is a positive and strong relationship between the size of the firms and their implementation of Industry 4.0 principles into their businesses. While more than half of the large firms have been implementing Industry 4.0 concepts, this ratio decreases as the firm size decreases. On the other hand, the number of companies who have not heard the topic Industry 4.0 increases as the firm size decreases. These results are in the line with the results of European Parliament Industry 4.0 Report suggesting that a large amount of investment is required by firms to catch the benefits of Industry 4.0 [32]. It is predicted that the necessary investment is about €40 billion annually until 2020 for Germany alone. In addition to capital and managerial needs, lack of qualified employees, and knowledge are the basic limitations that prevent companies from implementing Industry 4.0 technologies.

Table 5 General approach to the topic Industry 4.0

Statements	Number of firms	Ratio
We have been dealing with Industry 4.0 for more than 1 year.	65	15.3
We are trying to implement the concepts of Industry 4.0 right now.	49	11.5
We know the term Industry 4.0 but we haven't considered its implementation so far.	139	32.7
We have heard the term Industry 4.0 but we have no idea what exactly it covers.	90	21.2
We have not yet heard about the topic Industry 4.0	82	19.3
Total	425	100.0

Table 6 Summary of firms' approach to Industry 4.0 technologies by firm size

Statements	Firm size			
	Micro	Small	Medium	Large
We have been dealing with Industry 4.0 for more than 1 year, or we are trying to implement the concepts of Industry 4.0 right now.	9.4 %	14.9 %	28 %	55.2 %
We have not yet heard about the topic Industry 4.0.	35.8 %	23.4 %	13.1 %	4.8 %

In the next question, the managers are asked in what extent they apply Industry 4.0 principles and in which organizational department (unit) in their firm. According to the answers of the respondents, it is concluded that, 7.5 % of all firms implement Industry 4.0 principles in "finance and accounting departments" in advanced level. "IT department" follows "finance and accounting" with the percentage of 6.8 %. Following finance and accounting and IT departments, "production" (6.3 %), "product design" (5.9 %), "research and development" (4.4 %), "repair and maintenance" (4.2 %), "marketing and sales" (4 %), "purchasing" (3 %) and logistics (3 %) departments are using I4.0 principles in advanced level.

Table 7 lists the implementation degrees of the 9 basic technologies that constitute Industry 4.0. There are 9 technologies constituting Industry 4.0, which are autonomous robots, big data applications, cloud computing, cyber-security, simulation, additive manufacturing, system integration, internet of things and augmented reality [10]. The respondents are asked about the degree of their usage of each technology. They are given 1-7 Likert scale with the ratings from "1-never" to "7-advanced level". The resulting average scores are between 1.59 and 2.96 which are quite low, since the great majority of the firms responded as "never (1)". According to Table 7, the most used technology is cyber security with the mean of 2.96. It is followed by cloud technologies (2.22) and system integration (2.19), respectively. Having the mean of 1.59 augmented reality is the least used technology among these nine technologies. Although the means of implementation degrees are quite low in general, there are a numerous firms that use these technologies in an advanced level. Fig. 1 indicates the total number of the advanced implementers of each Industry 4.0 technology and their distribution by sectors.

Fig. 1 shows that cyber security is the most popular technology among all industries. While autonomous robots are widely used by electrical and electronic products manufacturers, system integration is mostly implemented by automotive manufacturers. The usage of big data and cloud technologies are relatively rare between the advanced users in all industries. We also used the ANOVA statistical method to test the differences between all types of sectors in implementation degrees of Industry 4.0 technologies. The probability value is below 0.05 in nine Industry 4.0 technologies. This result shows that there is statistically significant differences in the means of implementation degrees of Industry 4.0 technologies among the different types of industries.

The respondent firms are also asked in what extend the key concepts of Industry 4.0 are important to them (on a scale of 1 to 7). The results point out that, all of the concepts are important for the managers. As one can see in Table 8, the means of importance degrees are between 6.25 and 5.23, which are very close to the highest rate 7. According to the respondent firms, cyber security is the most important technology followed by autonomous robots and big data, respectively.

Among these nine I4.0 technologies, augmented reality is found to be the least common technology, since it has the lowest implementation degree with the mean of 1.59 and the lowest importance degree with the mean of 5.23. Hence, we can conclude that, augmented reality will be the most difficult I4.0 technology to introduce in the Turkish manufacturing sector.

Table 9 summarizes the correlations between implementation and importance degrees of Industry 4.0 technologies. Having a correlation coefficient $r = 0.822$, proves a positive and significant relationship between the implementation degrees of Industry 4.0 technologies and their importance to the firms. This result indicates that the manufacturing companies try to use the Industry 4.0 concepts which they find the most important.

Table 7 Implementation degrees of Industry 4.0 technologies

I 4.0 technologies	Number of firms	Mean	Standard deviation	Number of advanced users
Cyber Security	427	2.96	2.01	60
Cloud Technologies	425	2.22	1.63	19
System Integration	425	2.19	1.69	30
Internet of Things	425	2.06	1.58	19
Simulation Technologies	425	2.02	1.66	25
Big Data	425	1.94	1.55	18
Autonomous Robots	427	1.92	1.64	25
Additive Manufacturing	425	1.72	1.44	22
Augmented Reality	425	1.59	1.40	21

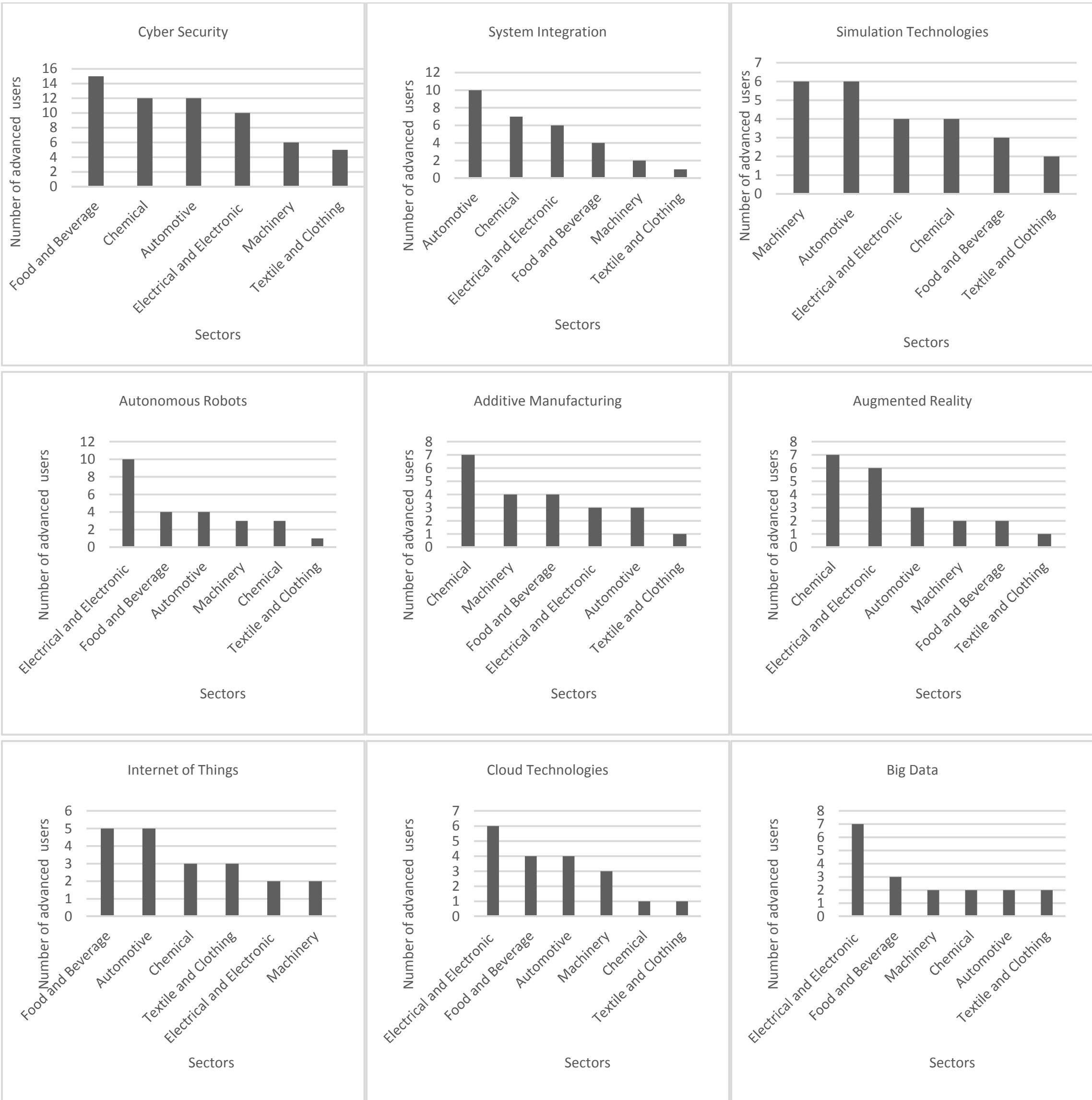

Fig. 1 Distribution of advanced implementers of Industry 4.0 technologies by sector

In this study, Cronbach Alpha (α) coefficient is calculated to test the reliability of the survey. There are 57 Likert-scaled questions in the survey. The overall Alpha (α) coefficient is calculated as 0.95 indicating a very high level of reliability.

In addition, the analyses indicate the existence of a positive and significant relationship between the implementation degrees of basic Industry 4.0 principles and the size of the firms. Fig. 2 shows the results of regression analysis between the number of manufacturing companies who are the advanced users of the basic Industry 4.0 technologies, and the size of these firms.

Table 8 Importance degrees of Industry 4.0 technologies

I4.0 Technologies	Observations	Mean	Std. Deviation
Cyber Security	426	6.25	1.30
Autonomous Robots	426	5.84	1.54
Big Data	426	5.59	1.57
System Integration	426	5.54	1.45
Internet of Things	426	5.52	1.53
Cloud Technologies	425	5.43	1.59
Simulation Technologies	426	5.39	1.59
Additive Manufacturing	426	5.32	1.62
Augmented Reality	425	5.23	1.63

Table 9 Correlations between the means of implementation and importance degrees

Correlations			
		Implementation degrees of Industry 4.0 technologies	Importance degrees of Industry 4.0 technologies
Implementation degrees of Industry 4.0 technologies	Pearson correlation	1	0.822**
	Sig. (2-tailed)		0.007
	N	9	9
Importance Degrees of Industry 4.0 technologies	Pearson correlation	0.822**	1
	Sig. (2-tailed)	0.007	
	N	9	9

** Correlation is significant at the 0.01 level (2-tailed).

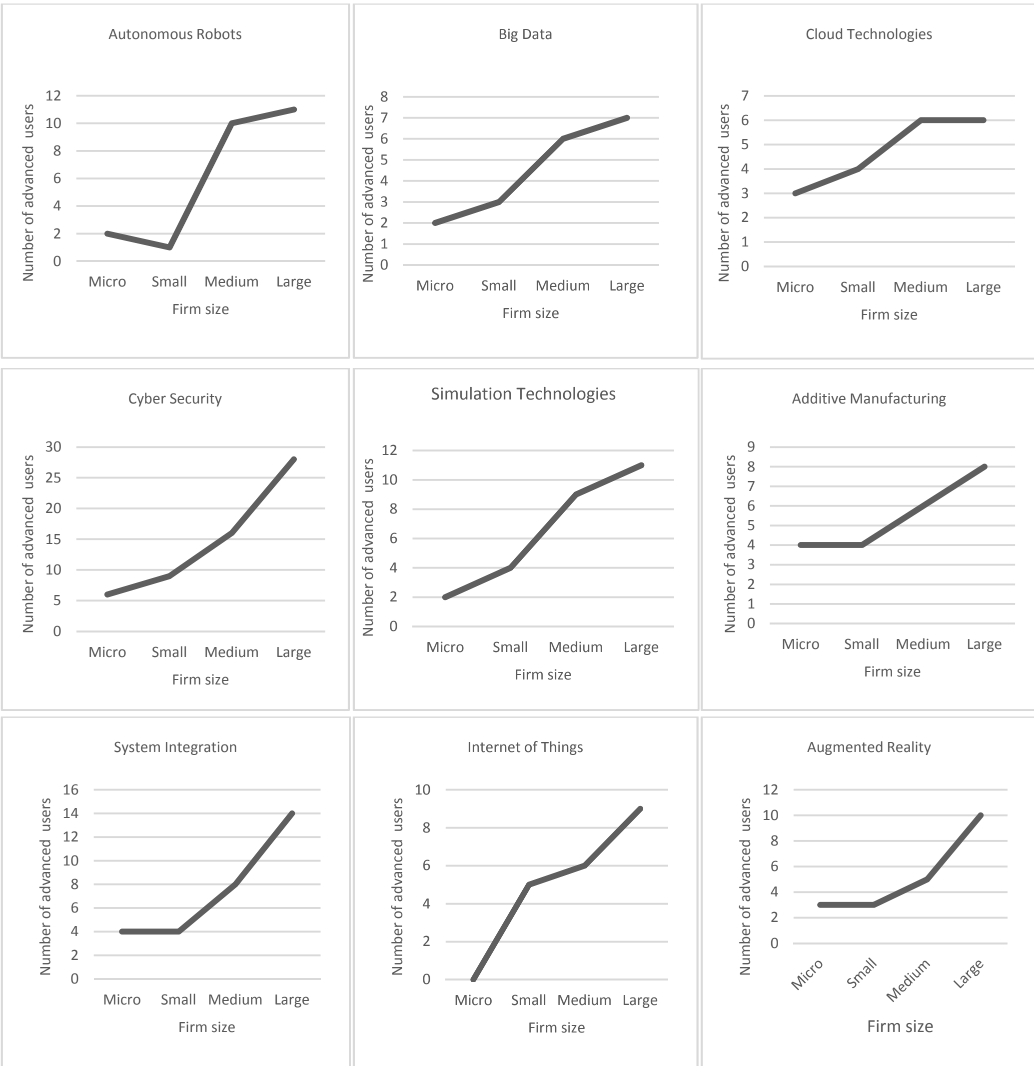

Fig. 2 The relationship between the number of advanced users and the firm size

According to Fig. 2 the number of advanced users increases as the firm size increases for the following technologies: big data, cloud technologies, internet of things, cyber security, and simulation. While there is no difference between micro and small firms for the technologies additive manufacturing and system integration, there is a slight decrease in autonomous robots for small-sized firms. However, the numbers of micro and small-sized firms are too few to make an accurate comparison. The increment is much more obvious in the middle-sized firms and large ones. ANOVA test are applied to test the differences between the firm sizes in implementation degrees of Industry 4.0 technologies. The probability value is below 0.05 in all Industry 4.0 technologies ($p \leq 0.05$). This result shows that there is a statistically significant differences in the mean implementation degrees of Industry 4.0 technologies among different sizes.

The survey results can be compared to the results obtained by the studies in other countries. The ratio of Turkish manufacturers who deal with I4.0 for more than one year is 15 % which is very low compared to the ratio in Czech Republic (40 %) [34]. Danish SMEs has an average readiness score of 2.9 (1 to 5-scale) [27]. Although the readiness score of Danish SMEs is interpreted as average, it is slightly higher than readiness scores of Turkish manufacturers. The firms are at the beginning of I4.0 process in Sweden and the main obstacle in transition to I4.0 is reported as lack of knowledge among Swedish firms [23] just like Turkish manufacturing firms.

6. Conclusion

This study presents the level of awareness and readiness of Turkish manufacturing firms for The Fourth Industrial Revolution. For this purpose, a survey was conducted with the managers of 427 firms of all sizes (micro, small, medium and large) operating in six sub-industries of Turkish manufacturing. The results indicate that the great majority of the firms are aware of the concept Industry 4.0 and its importance for their survival. Automotive, electrical and electronic, and machinery manufacturing are the first three industries in implementing Industry 4.0 principles while textile and clothing, and food and beverage manufacturing industries are the ones with the lowest ratios. The implementation level of Industry 4.0 technologies increases as the size of the manufacturing firms increase. It can be concluded that larger firms have relatively higher chance to reach the required financial or nonfinancial resources compared to small and medium-sized firms.

In this study, we examined nine basic Industry 4.0 technologies: autonomous robots, big data applications, cloud computing, cyber-security, simulation, additive manufacturing, system integration, internet of things, and augmented reality. Among these nine technologies, "cyber security" was found as the most popular Industry 4.0 technology in terms of both the importance and the implementation degrees. Although the implementation degrees of the related technologies are quite low on average, a number of firms, especially among large-sized firms, are advanced in implementing Industry 4.0 technologies. While the advanced users mostly implement the related digital technologies in their production, the priority of finance and accounting applications slightly surpasses the extensive usage in production.

Since there is a positive and significant correlation between the degrees of implementation and importance of basic Industry 4.0 technologies, we can conclude that the respondent firms try to use the technologies which are the most important (or familiar) to them. The priorities are defined by respondent managers according to their knowledge and understanding of the terms. When the survey results have been analysed, it is concluded that companies are confused about which digital application is considered within the scope of Industry 4.0. In order to help the manufacturing firms to catch the advantages of Industry 4.0 and ensure sustainable competitiveness, starting point might be to provide a comprehensive knowledge about Industry 4.0 technologies. By this way, firms would be able to decide the most adequate applications for their operations. Indeed, in order to catch the benefits of Industry 4.0, there is not only a need for significant amount of capital investment, but also for knowledge and training, strategic managerial approach, and qualified human resources.

We think that the biggest obstacle for fast implementation of Industry 4.0 into Turkish manufacturing industry is the lack of a collaborative strategy of digitalization. Such strategy needs acquiring and sharing a comprehensive up-to-date knowledge of technology. Furthermore, it should reflect the common goals and collaborative efforts of all members of supply chains in the manufacturing industry. The union of chambers, policy makers, researchers, and the sector leaders shall play a pioneering role in creation of such a technology sharing environment.

We hope, the results of this study help managers and decision makers in setting appropriate strategies and policies in adaptation to this new digital era. This is a preliminary study that reveals the awareness of the manufacturing firms about Industry 4.0 and their approach to Industry 4.0. Moreover, this research reveals the implementation and importance degrees of basic technologies related to Industry 4.0 for the Turkish manufacturing firms. In order to fully understand the current business environment and define a road map for manufacturers, future studies may focus on following issues: Corporate strategy for digitization, qualified workforce, organization and culture, infrastructure and other necessary resources.

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