CHAPTER 4

DATA IN THE CONTEXT OF INDUSTRY 4.0

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Abstract

Today, every sector, not least industry, has been affected by the development of technology. With the breakthrough development of technology, Industry 4.0 has emerged with the concept of big data. Data is the most important element in the process of creating information. This study aims to deal with the subject of Industry 4.0 which has attracted great interest in the global field in the context of big data. Studies concerning Industry 4.0 and related data are examined in our study through a systematic literature review. Web of Science database and "industry 4.0 and data" keywords were used for our article search. A preliminary evaluation was performed for 20 articles meeting the objective of this study which were selected for detailed examination. When the studies on Industry 4.0 and data are analyzed, we can determine that studies with big data, digitalization, internet of things, digital twin, cyber-physical systems, smart factories and cloud computing are prominent. Moreover, when the countries where the articles were published were analyzed, it was found that China was the most cited and studied country in this field. It is believed that the results of this examination will enlighten people working in this field and direct future studies.

Keywords: Big data, Industry 4.0, Literature review

1. Introduction

Nowadays, the importance of knowledge is an undeniable fact. Decision-makers need the right knowledge in order to make decisions with minimum errors, to develop effective strategies and business models. Knowledge should be revealed by making maximum use of availableresources. For this purpose, the most important source is data, which is the building block of knowledge. Data is obtained from various sources, recorded and analyzed in the best way. Much effort is being put into developing various methods for transforming data into meaningful and useful information. On the one hand, the information and communication technologies developing day by day significantly increase both the computing power and memory capacity of computers, and on the other hand, different devices, platforms, and applications that enable data collection are being developed. All these improvements allow for the storage of much larger amounts of different types of data. It is possible to say that data is collected in many areas from health to education, from security to economy, from tourism to transportation. Data has been continuously recorded and stored in virtual environments through many systems such as patient tracking, appointment and pharmacy systems, student information systems of primary, secondary and higher education institutions, information and document management systems used in public/private institutions or organizations, social media platforms, geographic information systems, seismic record collectors, satellite and air vehicles. This has led to an increase in the amount of data stored day by day, and data has begun to pile up in stacks. In addition to the increase in quantity, non-structural data, which is irregular, non-conforming, and contains text, sound, and image content, have also been stored as well as structural data, which is generally recorded in tables and conforms to a predetermined pattern. As a result of all these developments, the concept of big data has been mentioned. In this direction, it can be said that data-based concepts and methods are shifted to the big data axis.

On the other hand, one of the areas affected by the development of information and communication technologies is industry. Industry has passed through three main periods and reached the fourth period mentioned today. In addition to the developments in the third period, the integration of high technologies such as robotics and digital technology into production systems, and the use of the Internet more effectively in these systems brought about a new era in the field of industry. There has been a need for a systematic approach in order to integrate the systems (especially smart systems) equipped with the new technologies mentioned above in production areas in order to make production continuous in the factories and to minimize breakdown (Bagheri, Yang, Kao, & Lee, 2015). In this direction, the fourth period, which is mentioned together with the concepts of cyber-physical systems, the internet of objects, smart factories, etc., continues to evolve today. This period is called the 4th Industrial Revolution or Industry 4.0. Within the scope of Industry 4.0, the use of ubiquitous information and communication technology (ICT) infrastructure is considered to contribute greatly to sustainable production. (Stock & Seliger, 2016). Industry 4.0, also known as Intelligent Manufacturing, Industrial Internet, or Integrated Industry (Hofmann & Rüsch, 2017), is defined as a network approach in which components and machines become intelligent and are part of a standardized network that is built to strictly defined Internet standards (Kolberg & Zühlke, 2015). One of the factors that accelerated the transition to Industry 4.0 is the surprising increase in data volume and computing power and capabilities (Baur & Wee, 2015).

This study aims to deal with the subject of Industry 4.0 which has attracted great interest in the global field in the context of big data. In this respect, firstly, the basic concepts of Industry 4.0, data and big data have been discussed and a literature review has been conducted. In the literature research, Industry 4.0 studies carried out within the framework of both general applications and data-big data have been examined, and the importance of data and big data concepts for Industry 4.0 and its future have been discussed in the discussion and conclusion section.

2. Industry 4.0

With the opportunities provided by developing technology for the benefit of human beings, it is seen that there are shifts to digital environments in many areas from finance to education, and from health to safety in terms of habits and business processes. Shopping on digital platforms, the use of internet banking, the recording of physical documents on computers, the use of e-mail instead of mail, the selection of students' courses , the announcement of exam results, and the sharing of lecture notes through management information systems can all be shown as examples of this situation. This is referred to as digitization or digital transformation. Digital transformation is a process that results in differentiation in the fields of enterprises such as products, organizational structures, and automation processes with the integration of digital technologies into business models (Matt, Hess, Benlian, & Wiesbock, 2016). Digital transformation is the deep and rapid transformation of business activities, processes, competencies, and models by using the changes and opportunities brought about by digital technologies in order to fully strengthen the impacts of these technologies on society in a strategic and priority manner (Demirkan, Spohrer, & Welser, 2016). The potential benefits of digitization are enormous, especially in terms of sales or productivity increases and innovations in value creation (Matt, Hess, & Benlian, 2015).

One of the areas where digital transformation shows its effect is industry. Industry has reached the present day by passing through different periods together with the systems developed according to the conditions of the day and included in the production process. These periods are called the first, second, third and fourth industrial revolutions. The systems that affect the transformation can be counted as steam-powered mechanical systems, electrical energy-powered systems, computer-based automation systems, and finally, intelligent systems that can communicate with each other via the internet and decide on their own.

Globalization has lifted international borders and it has led to a shift in the competition to a different dimension in all areas. Increased product and process complexity, variable market characteristics, shortened product, market, technology, and innovation cycles are some of the challenges in the competitive environment (Rennung, Luminosu, & Draghici, 2016). In this respect, various strategies that are innovative and increase productivity are developed and different investment proposals are evaluated in order to survive under tough competitive conditions. The purpose of assessing savings through various investment options or making strategic decisions is to generate more revenue in the future. In this case, one of the important points is to provide the highest return with minimum risk. On the other hand, The development of information and communication technologies and the increasing importance of information have attracted the attention of countries in order to make new initiatives especially in the field of industry. Also, the advantages and disadvantages of shaping strategies and investments around changing social habits, knowledge and new technologies have started to be discussed. Especially with the integration of internet and sensor technology to existing production systems, a new production model has been proposed. This model, which is referred to as Industry 4.0, was set out in 2011 by a proposal file submitted to the German government by a working group under the direction of Robert Bosch GmbH and Henning Kagermann. With the final report announced at the Hannover Fair in Germany in 2013, it has become a topic of interest on the world agenda. Factors that accelerate the transition to Industry 4.0 include increased amount of stored data, increased computing power of computers, improved analytical and business intelligence solutions, improved interfaces in human-machine interaction, and the ease of transforming digital guidelines into the physical world (Baur & Wee, 2015).

Although it seems to be the development of computerized manufacturing systems that led to the third industrial revolution with new technologies, Industry 4.0 is based on a network model that includes not only the automation of value chain elements but also the integration of these tools with continuous communication and real-time features (Hopali & Vayvay, 2018). In this direction, Industry 4.0 has a concept shaped around the concepts of cyber-physical systems, internet of things and services, wireless communication, industrial internet, intelligent production and cloud-based production (Almada-Lobo, 2015; Vaidya, Ambad, & Bhosle, 2018). Industry 4.0 is a model associated with data exchange based on connectivity between new technologies on the one hand, and with automation on the other hand (Fantoni, Chiarello, Fareri, Pira, & Guadagni, 2018). To put it more clearly, it is a production model in which a real factory has one-to-one representation in a virtual environment, where machines, robots and people can communicate with each other via the internet and intelligent machines (robots) can manage themselves by analyzing the data, which is collected from different sources with the help of sensors, in decision systems. In this way, flexible and fast solutions can be produced and resources are used more efficiently. The Industry 4.0 model can be summarized as follows (Koçoğlu, 2018):

- Forming intelligent factories with a modular structure consisting of sensors that can detect the environment and intelligent robots carrying out production activities,
- Creating a cyber-physical system in which a virtual object of every object in physical structure is created and communication between objects and people is provided via the internet,
- Recording the data flowing into the system,
- Obtaining high quality and efficient production with less error by processing this big data.

With the new production system proposed within the scope of Industry 4.0, a higher production automation level is targeted by optimizing production management and with the production safety and training of employees (Wu & Duan, 2018). Industry 4.0 aims to make factories smart enough in terms of adaptability, resource efficiency and improved integration of supply and demand processes (Varghese & Tandur, 2014). The benefits of Industry 4.0 with the subjects on the use of idle data, production time and personalization are strengthening this model (Schmidt et al., 2015).

In order to make Industry 4.0 more meaningful, the functions of new technologies used for this production model and their roles in the system must be known. In this context, the most important components of Industry 4.0 are explained below.

Cyber-Physical Systems (CPS): This is an essential part of the Industry 4.0 model. Cyber-Physical Systems are the integration of physical processes with the virtual processes and physical processes are monitored and controlled through embedded computers, sensors, various software and networks (Lee, 2008). These two systems communicate over the cyber-physical system and thus work synchronously with each other. The ability of these systems to interact with the physical world and expand their capabilities through computing, communication, and control is crucial to future technological advances (Baheti & Gill, 2011).

Internet of Things (IoT): Communication in the future will not only be between people. Similarly, access to information will not only be requested by people. On behalf of people, machines will try to communicate with other machines and collect data (Tan & Wang, 2010). All this communication will take place via the internet. Internet of things whose architecture is technically based on data communication tools, primarily RFID, aims to facilitate the exchange of information between all objects defined on the network (M. Wu, Lu, Ling, Sun, & Du, 2010). In other words, all objects (human or machine) defined in the cyber-physical system will use the internet of things for communication.

Smart Factory: The change in the close connection and communication between products, machinery, transport systems and people by means of the other technologies mentioned above also indicates a change in the existing production logic (Hofmann & Rüsch, 2017). The factories of the future will be much more than a system where production resources are interconnected and where they automatically exchange information. According to this, a sufficiently intelligent system will emerge that can predict the problems that may arise and determine the required maintenance times, control the production process and manage the machines (Qin, Liu, & Grosvenor, 2016). With smart factories, the aim is to realize a flexible and adaptable intelligent production process that is able to adapt quickly to change, is based on automation, manages the machine by reducing human intervention and uses resources efficiently.

Cloud Computing: Instead of meeting their hardware, system and software needs within the framework of the resources in the enterprise because of disadvantages in terms of cost, flexibility, complexity of infrastructure, and storage of data, companies provide these needs from outside. Cloud computing is a flexible and inexpensive technology that provides services including infrastructure, software, hardware, platforms, and other information technology infrastructure resources when needed. Users can use the services provided to them according to application requirements and based on access to computer and storage systems (Zhou, Liu, & Zhou, 2015).

Human-Computer Interaction (HCI): With the Industry 4.0 model, the integration of new technologies into production systems is becoming more complex due to a growing communication network. In addition to this, it is clear that there will be changes in the duties and responsibilities of people within this system. Also, it should be mentioned that it will be a large system where people will interact with computers and machines. The field of study on interaction and communication between computer and human is called human-computer interaction. Human-computer interaction studies, which started with the aim of creating highly usable interface designs, have been expanded with the inclusion of tasks, actions, explanations, reasons, and discussions in the study (Fischer, 2001). Human-computer interaction is concerned with how people benefit from existing systems and devices, as well as the design of new interactive systems and devices that will enhance human performance and experience (Carroll, 2006). As a part of human-computer interaction, virtual and augmented reality concepts gain importance in the Industry 4.0 model. Virtual Reality (VR) is a technology that allows the user to simulate and interactively explore the behavior of a CPS-based production system (Gorecky, Schmitt, Loskyll, & Zühlke, 2014), while Augmented Reality (AR) is a technology that integrates real and virtual object (world) images using various computer graphics. These two technologies maximize human interaction with the computer system via a display interface. For example, computer-based training for factory employees can be carried out in a one-to-one simulation of a real factory created using VR or AR technologies, thus the effectiveness of the training can be increased.

Big data is also among the aforementioned components of Industry 4.0. In this study, the concept of big data is discussed in more detail below.

3. Big Data

Before the concept of big data, the concepts of data-information-knowledge should be considered. Data is a collection of unprocessed characters that describe any state, object, or event and hold their values. Information is defined as data when its form and benefit are increased as a result of various processes such as calculation, merging, categorizing and summarizing (Ackoff, 1989). The data alone does not make any sense. The meaning and benefit of information are limited. Therefore, data needs to be transformed into knowledge in order to make it meaningful, in other words, useful for predicting, developing strategies or making decisions. The content obtained as a result of the integration of information through a certain filter, analysis and synthesis, individual experience and expert opinions for the purpose of creating benefit and value is called knowledge. A significant portion of the information that is considered important is used by recording and is considered to have been transformed into knowledge only when it becomes of value for individuals or institutions (Dinçmen, 2010). As can be seen, information can be obtained as a result of the conversion of data, whereas knowledge can only be built on the information obtained from the data. The link between data, information, and knowledge is represented by the knowledge hierarchy pyramid (Figure 1). When the pyramid is examined, value and meaning increase in the direction from data to knowledge , as indicated by the definitions, and decrease in the opposite direction.

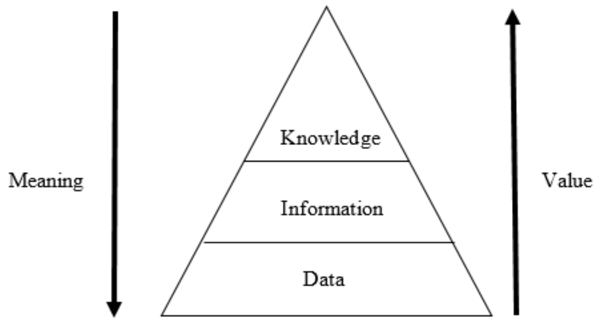

Figure 1: Knowledge hierarchy pyramid (Chaffey and Wood, 2005)

The rapid development of information and communication technologies has increased the computing power of computers and has enabled the creation of larger storage areas for the recording of data. Accordingly, all kinds of data have been stored in order to reach knowledge. Every transaction we perform in the market vault or online banking, all kinds of results obtained in health screening (blood values, MR / BT images, physical examination results, etc.), camera images obtained in different areas such as shopping malls, schools, hospitals, squares, call centers' voice recordings, such as the values produced by the machines in production lines in factories, all these are examples of this recorded data. In addition to the data currently being recorded, companies that discover the importance of the data will start using real-time data from various descriptive devices to understand their workflows in detail, develop innovative products and services, and keep pace with changes (Davenport, Barth, & Bean, 2012). By taking this situation into consideration, it is clear that the size of the recorded data increases day by day. Big data has emerged in connection with the challenges that organizations face in trying to cope with rapidly growing data sources (Villars, Eastwood, & Olofson, 2011). Big data is the term used to describe data sets that cannot be managed by existing methodologies due to both the size and complexity of the structure (Fan & Bifet, 2013). Big data is a data set obtained from different sources, which is continuously increasing in volume, structured in terms of structure, semi-structured and unstructured data and difficult to manage. As can be seen from the definition of big data, there are three main components.

These are volume, velocity, and variety. In addition to these components, veracity, validity, variability, volatility, visualization and value are among the other components (Demchenko, de Laat, & Membrey, 2014; Owais & Hussein, 2016). The quality of this data set is far from perfect due to its large volume, speed, and heterogeneity (Saha & Srivastava, 2014), and its analysis is not possible with standard methods. However, the big data obtained by combining the data collected from various incompatible systems can be analyzed at an advanced level with the developed big data technologies (Witkowski, 2017).

Obtaining knowledge using big data has become a key way for businesses to know themselves and their competitors better and perform better (Manyika et al., 2011). As in all fields, in production also, it is important to process the data correctly and convert it into useful knowledge. In the industrial field, big data emerges with the combination of data generated by values such as vibration-pressure, which can be measured by various sensors installed as a result of intelligent and cyber-physical systems in the manufacturing process, data obtained through communication protocols between all assets in the system and historical data (Lee, Kao, & Yang, 2014). The big data obtained in this direction can be used to increase the quality of pruduction, reduce resource wastage and maintenance costs, shorten the material supply and production time, faciliate more efficient planning, and increase efficiency.

Until this section, the Industry 4.0 model, its components and big data concepts have been discussed and basic explanations have been given. In the next section , the literature research and its results are shared.

4. Methodology

Within the scope of the study, research was carried out on the examination of articles through systematic review. The article selection was made on the Web of Science (WOS) database.

The articles were determined according to the index status of the journal, the number of citations received by the articles and the keywords which had previously been determined.

Articles published between 2013-2019 were searched using the WOS database. Since the concept of industry 4.0 became official as of 2013, 2013 was chosen as the start of publication date.

- "Industry 4.0 and data" keywords were used for article search. Keywords were searched in topics of the articles.

- The articles selected for examination were published in journals indexed by Social Sciences Citation Index (SSCI), Sciences Citation Index Expanded (SCI-Expanded), Arts & Humanities Citation Index (A&HCI), Book Citation Index- Science (BKCI – S), Book Citation Index- Social Sciences & Humanities (BKCI-SSH) and Emerging Sources Citation Index (ESCI).
- “Highly Cited in the Field” and “Hot Papers in Field” options were selected and all articles were listed in the WOS Database.
- The number of articles was limited to 30. Therefore, only the first 30 articles were selected for evaluation.
- A preliminary evaluation was performed for 30 articles. For the purpose of the study, only 20 articles met the objective of this study. As a result of the preliminary evaluation these 20 articles were selected for detailed examination.

The selected articles were examined in terms of general research subject, application sector, applied methods and acquired general results. All articles were summarized under these terms.

5. Findings

Twenty articles published between 2013 and 2019 were examined in this study. The summary of the article evaluation is shared below and a summary table is given in Appendix.

Ardito, Petruzzelli, Panniello, & Garavelli (2019) conducted research on the digital technologies used to show the connection between supply chain management and marketing processes and to manage related interfaces. Real samples and patent analysis methods were used for this aim. United States Patent and Trademark Office (USPTO) database was used to find the categories defined within the scope of the research. Patent count analysis was performed at technology level. Annual patent count was used as a measurement of innovation efforts in time. A tendency for a sharp increase was observed for patents especially since 2013. This article becomes prominent as one of the studies supporting the integration of supply chain management and marketing regarded as a key success factor to survive in a competition environment and to acquire an outstanding financial performance. From a manufacturer’s perspective, Gu, Guo, Hall, & Gu (2019) suggested an integrated architecture to acquire an efficient and productive Extended Producer Responsibility (EPR) through a case study approach. Based on the selected case study, Haier’s architecture of a smart refrigerator facility of integrated information systems and facilitated life cycle management was observed. The objective of Xu & Duan, (2019) was to better remark the importance of cyber-physical systems and big data for Industry 4.0. They stated that Industry 4.0 was especially supported by the German government and since it is a new concept formed by an advanced production vision, there are few studies in the literature on the big data and cyber-physical systems which are among the constituents of this concept. Cyber-physical systems are critical constituents representing the efficient and productive management of data acquired from the basic infrastructure of Industry 4.0 and the big data with the data acquired from cyber-physical systems. In the study, they emphasized the necessity of big data technologies which provide for the processing of the big data and which consistently improve the scalability, safety and efficiency of cyber-physical systems.

Ivanov, Dolgui, & Sokolov (2019) investigated the impact of digitalization and Industry 4.0 on the ripple effect and supply chain disruption risk control analytics of the supply chain. This study demonstrated that digital technologies increased the responsiveness and capacity elasticity of demand at the proactive stage. It was also stated that this condition may have a positive effect on the decreases in risk, thus decreasing inventory in the ripple effect control. It was detected that depending on additive production, shorter delivery times and digitalization would increase the effect on inventory control. Wan et al. (2019) presented a multi-dimensional data indexing scheme which was designed to solve the range query and is effective in terms of energy and time. This scheme collects multi-characteristic sensor data in an energy and time efficient manner. Hierarchical intranet storage was used to provide quick query responses. Through performance evaluation, the efficiency of the suggested scheme compared to other data structures was also proven. In their study, Tao & Qi (2019) focused on the fact that new information technologies particularly promote smart manufacturing, and they aimed to present a general framework on the subject. They stated that new technologies such as internet of things (IoT), cloud computing, big data, mobile Internet and cyber-physical systems (CPS) would especially play a significant role in promoting smart manufacturing. Service-oriented smart manufacturing (SoSM) framework using the afore-mentioned technologies was also suggested in the research. It was stated that the suggested framework had a critical importance particularly in the facilitation of smart manufacturing.

Reyna, Martín, Chen, Soler, & Díaz (2018) conducted a study to detect the difficulties in IoT's integration with blockchain and to analyze potential future advantages. Key points through which Blockchain technology may facilitate the improvement of IoT applications were determined and also an evaluation was performed to prove the applicability of using blockchain knots in IoT devices. At the end of the study, it was predicted that Blockchain would be revolutionary in IoT. Li (2018) compared Germany's "Industry 4.0" and China's "Made-in-China 2025" and estimated China's locus in "Made-in-China 2025". Data and information from the World Bank Data and China's National Bureau of Statistics were used to analyze the potential of advancing the plan from "Made-in-China" to "Designed-in-China". The acquired results show that China is not the workforce market with the lowest cost in the current situation. It was also found that China is not the strongest player in the high technology arena and that well-established industrialized countries such as USA, Germany and Japan actively use digital technology to build new industrial environments, to manufacture new products and to improve their well-established trademarks. But it was stated that China has an ascending course in terms of manufacturing potential, research development and human capital investment subjects. In their research, de Sousa Jabbour, Jabbour, Foropon, & Godinho Filho (2018) suggested a framework providing for the integration of two industrial waves (industry 4.0 and sustainability) and promising the restructuring of present manufacturing and consumption habits. It was emphasized that Industry 4.0 and industrial sustainability had improved separately until today and that the integration of these two factors is at the beginning stage. In the study, 11 critical success factors, which should be carefully considered by institutions especially during the concurrent application of Industry 4.0 and environmentally-sustainable manufacturing, were pointed out. These factors were listed as management and leadership, being ready for organizational change, decisiveness of senior management, strategic cooperations, training and capacity increase, keeping high motivation of the employees, teamwork, building a company culture, communication, project management and understanding regional differences. Finally, it was stated in the study that Industry 4.0 may increase environmentally sustainable manufacturing especially by improving green products, green production phases and green supply chain management as never seen before.

Moeuf, Pellerin, Lamouri, Tamayo-Giraldo, & Barbaray (2018) carried out a literature research on the currently applied researches performed within the concept of Industry 4.0 in terms of SMEs. The results show that SMEs did not use all available resources to apply Industry 4.0 and generally limited themselves to Cloud Computing and Internet of Things constituents of Industry 4.0. From a different standpoint, it was detected that SMEs adopted Industry 4.0 concepts only to follow industrial phases but there were no actual applications for manufacture planning. Finally, it was determined that Industry 4.0 projects in SMEs remained as cost-oriented initiatives and did not transform into an actual work model. In the research conducted by Qi & Tao (2018) to determine the role of the mutual use of digital twin and big data in the improvement of smart manufacturing, it was concluded that both technologies played a significant role in promoting smart manufacturing. It was stated that digital twin concept would lead to the preparation of cyber-physical integration basis by providing the manufacturers with the chance to manage real-time matchings between a physical object and its digital representation. Some interesting aspects of this study were the facts that through the correct analysis of big data, digital twin-driven smart manufacturing can be performed in a more sensible and predictive way and would be more rational in many aspects and advantageous for absolute manufacturing management. As a result, digital twin and big data were detected as two factors complementing each other to assist smart manufacturing. In their research, Chen et al., (2018) aimed to determine the hierarchical architecture of a smart factory and then to analyze its different layers. The main constituents of the basic technologies at physical source layer, network layer and data application layer in the smart factory were analyzed. It was emphasized that investigating the key technologies would not mean the integration of information technology only as the main structure, but it should also cover traditional disciplines such as control theory, mechanic technology, material and energy. It was stated that with the progression of big data technology, the product quality and manufacturing efficiency of databased virtual manufacturing mode would increase, and the energy consumption would decrease. It was also stated that big data-dependent smart manufacturing would provide the acceleration of the industrial revolution. Müller, Kiel, & Voigt (2018) examined the factors improving the application of Industry 4.0 and the role of sector opportunities and difficulties in terms of sustainability. A research model covering the opportunities on Industry 4.0 and the difficulties primarily faced in its application was suggested in the study. To test the model, PLS-SEM (Partial Least Squares Structural Equation Modeling) was applied on a sample acquired from 746 German manufacturing companies from five industrial sectors. The results show that as much as strategic and operational ones, environmental and social opportunities also have positive impulses on the application of Industry 4.0. On the other hand, it was observed that the difficulties with competitive power and future applicability, as well as organizational and manufacturing suitability, prevented the progress.

In their research which was conducted to suggest and apply a big data solution for active preventive maintenance in manufacturing environments, Wan et al. (2017) built the system architecture required primarily for active preventive maintenance. Analyzing the collection method according to data characteristics in big data production, cloud data processing including cloud layer architecture, real time active maintenance mechanism and offline prediction and analysis method was performed. Prototype platform was analyzed, and the suggested active preventive maintenance method was compared to the traditional method. As a result, it was shown that the suggested model had the potential of accelerating the Industry 4.0 application. The aim of the study performed by Sikorski, Haughton, & Kraft (2017) was to investigate the applications of blockchain technology related to the 4th Industrial Revolution (Industry 4.0) and to present a sample of chemistry industry using block chain to facilitate machine-machine interactions. In the presented scenario, two electricity producers trading with each other through a block chain and an electricity consumer are present. The producers present energy trading (in kWh) in foreign exchange (USD) in a dataflow. The consumer reads and analyzes the offers and tries to meet the energy demand with minimum cost. When an offer is accepted, it is applied as an atomic exchange. This study contributes to the clear application of the described scenario and its technical details. In current literature, Liao, Deschamps, Loures, & Ramos (2017) stated that the efforts to systematically examine the condition of the industrial revolution wave are still inadequate. For this aim, examining the academic progresses in Industry 4.0, they covered this deficit in their research. A systematic literature search was performed to analyze academic articles on Industry 4.0. Results acquired through the general data analysis and specific data analysis of the articles included in the research were shown and discussed. These results not only summarized the available research activities, but also covered the present deficiencies and potential researches for the future, offering a research suggestion. It was stated that the findings of this inspection can be used as the basis of future studies on Industry 4.0 and related subjects. Starting from the target to develop data-based manufacturing information system architecture, Theorin et al. (2017) developed The Line Information System Architecture (LISA) designed to provide flexible factory integration and data use. The main targets of LISA were stated as focusing on the integration of device and services at all levels and supporting constant recoveries in the information visualization and control in addition to the integration of new smart services.

In their research, Wan et al. (2016) presented a new concept suggestion for industrial environments by presenting software-defined Internet of Things to make the industrial wireless networks more flexible. IoT architecture was analyzed in detail and the information interaction between different devices was explained. As a result, the interface of a software-based IoT architecture was designed to manage physical systems. In their research, Wang, Wan, Zhang, Li, & Zhang (2016) presented a smart factory framework combining industrial network, cloud and supervisory control terminals with smart workshop objects. Then they classified smart objects based on different agent types and defined a coordinator in the cloud.

Based on this model, a smart mechanism was suggested to provide the cooperation of agents and crashing was prevented through improving the decision making of the agents in the model and the actions of the coordinator.

Zhan et al. (2015) stated an increase in the use of Evolutionary Computation (EC) algorithms. It was stated that it would be advantageous to investigate the general role of EC in the development of cloud computing and its planning for the big data via the Internet. It was also asserted that deep learning in EC algorithms for predictive data analytics for cloud computing scheduling would be one noteworthy theme in the Industry 4.0 stage. At the beginning of Industry 4.0, planning for big data and cyber-physical cloud computing was explored. It was found that research in this field was just in its earliest stages and newer issues would arise with the fast improvement of cloud computing, big data and Internet of Things.

5. Discussion and Conclusion

Having useful information is very important for enterprises to understand their competitive environment and their position in this environment, to evaluate their internal operations correctly and to make the necessary strategic decisions with minimum errors. Realizing this situation, institutions and organizations have continuously tried to record all kinds of data they can obtain. Therefore, besides resources such as labor, materials and equipment, information has been among the important sources. Such an increase in the importance of information has resulted in continuous data collection from all possible sources. Developing information technologies and increasing expectations led to the recording of data with a different structure and an increase in volume. This resulted in a large volume of data sets that are difficult to cope with and the concept of big data was put forward. Moreover , the industry has now entered a new transformation process which is called Industry 4.0. The basic logic of Industry 4.0 is based on the representation and communication of people, machines, robots and all other physical components in the production system through cyber-physical systems and the internet of objects. Within this structure, data will be generated both by sensors and during the communication process with the internet of objects. Therefore, within the scope of Industry 4.0, data and even big data become one of the important components. Smart factories targeted at Industry 4.0 and efficient self-decision systems can only be obtained by processing this data and producing the accurate knowledge.

Since the official launch of the concept in 2013, the number of studies carried out within the scope of Industry 4.0 has been increasing. In this study, it was seen that the articles examined are mainly made up of cyber-physical systems, smart factories, digitalization, internet of things, cloud computing, and digital twin. When the evaluation is made on the basis of big data, it was seen that the subject is considered as one of the important components of Industry 4.0 but that it is not in the focus of the studies. This situation is considered to be of importance because the studies related to Industry 4.0 are still in the conceptual, basic application and model installation stage. In the second part of the study, four steps of Industry 4.0 were mentioned. The third and fourth of these steps are the collection of data, following the integration of robot and sensor technologies into the production systems of cyber-physical systems and the completion of the infrastructure of Industry 4.0. Therefore, after the establishment of the Industry 4.0 infrastructure and production started to be performed within the scope of this model, the data produced will increase and the methods and technologies required for processing this big data will increase This is an indication that big data studies will gain more importance and speed.

In some of the studies examined, it was seen that predictive maintenance particularly comes to the forefront. Predictive maintenance is used to monitor the equipment, to estimate possible failures before the failure occurs, to take the necessary measures and to reduce the negative effects of time, cost and efficiency. In predictive maintenance, big data analysis methods and technologies are utilized due to the developments in the industrial field, the machines that have turned into a complex structure and the increasing data size as a result. Some of important results of Industry 4.0 and big data are the reduction of maintenance costs with the information obtained from the analyzes and the self-determination of the maintenance times of the machines without the need for any control.

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The concept of Industry 4.0 is a production model introduced in Germany and the first studies were carried out in European countries, especially in Germany. Other industrialized countries that do not want to fall behind in the competition have been included in this industrial movement. America, Japan, Canada, and China are among these countries. However, some of these countries have evaluated the proposed Industrial 4.0 model from their own perspectives and have proposed new models. Society 5.0 is one of these models, which Japan specifically suggests. Our research shows that most of the articles that are obtained as a result of the article review conducted in this study are based in China. It is clear that China, which has taken important steps in the field of industry and economy, also gives importance to Industry 4.0. When evaluated in general, it is evident that there is a lot of interest in this new production model, called Industry 4.0 or otherwise, and that the industry will shift rapidly towards this new model on a global basis . Accordingly, scientific research articles show that different countries from all regions of the world are interested in this subject and try to improve themselves in this field. For countries that do not want to be left behind in this movement of change, it can be said that it will be a tight competition.

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Appendix:

Author- Year	Country	Keywords	Field of Application
Ardito, L., Petruzzelli, A. M., Panniello, U., & Garavelli, A. C. (2019).	Italy	innovation, marketing, internet of things, patent analysis, cloud computing, supply chain management, big data analytics, industry 4.0, cyber security	supply chain management marketing integration
Gu, F., Guo, J., Hall, P., & Gu, X. (2019).	China	Industry 4.0, extended producer responsibility, information sharing, integration, life cycle management, smart factory, sustainability	an integrated architecture presentation to implement extended manufacturer responsibility in the context of Industry 4.0
Xu, L. D., & Duan, L. (2019).	United States of America	Industry 4.0, IoT, cloud computing, cyber-physical systems, big data,data science, industrial information integration, engineering	importance of cyber-physical systems for Industry 4.0
Ivanov, D., Dolgui, A., & Sokolov, B. (2019).	Germany, France, Russia	supply chain dynamics, supply chain risk management, supply chain resilience, supply chain design, supply chain engineering, Industry 4.0, additive manufacturing, blockchain, big data analytics, ripple effect	the impact of digitization and Industry 4.0 on the supply chain management
Wan, S., Zhao, Y., Wang, T., Gu, Z., Abbasi, Q. H., & Choo, K.-K. R. (2019).	China, Germany, United Kingdom, United States of America	range query processing, multi-dimensional data indexing, voronoi diagram, IoT energy efficiency	multi-dimensional data indexing approaches in applications of Industry 4.0 and internet of things (IoT)
Tao, F., & Qi, Q. (2019).	China	big data, cloud computing, cyber-physical integration, internet of things (IoT), manufacturing service, smart manufacturing.	new IT driven service-oriented smart manufacturing: framework and characteristics
Reyna, A., Martín, C., Chen, J., Soler, E., & Díaz, M. (2018).	Spain	internet of things, blockchain, smart contract, trust	blockchain and IoT integration applications
Li, L. (2018).	United States of America	Made-in-China 2025, Industry 4.0,emerging economy, cyber-physical systems (CPS), internet of things (IoT) manufacturing capability, human capital, R&D, smart factory, collaborative robots	comparison of "Made-in-China 2025" and "Industry 4.0"
de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Foropon, C., & Godinho Filho, M. (2018).	France, Brazil	industrial wave overlap, Industry 4.0, sustainable operations, environmentally-sustainable manufacturing,critical success factors	critical success factors of Industry 4.0's potential to change the environmentally sustainable production wave

Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S., & Barbaray, R. (2018).	France, Canada	production control, Industry 4.0; smart manufacturing, operational improvement, SME, SMB	industrial management practices of SMEs in Industry 4.0 period
Qi, Q., & Tao, F. (2018).	China	big data, digital twin, smart manufacturing, comprehensive comparison, convergence.	comparison of smart manufacturing and big data for digital twin and Industry 4.0
Chen, B., Wan, J., Shu, L., Li, P., Mukherjee, M., & Yin, B. (2018).	China, United Kingdom, Germany	smart factory, big data, cloud computing, cyber-physical systems, industrial Internet of Things.	the role of Industry 4.0 in smart factory applications
Müller, J. M., Kiel, D., & Voigt, K.-I. (2018).	Germany	Industry 4.0; industrial Internet of Things, sustainability; implementation structural equation modeling, German industry sectors	Industry 4.0 in the context of sustainability
Wan, J., Tang, S., Li, D., Wang, S., Liu, C., Abbas, H., & Vasilakos, A. V. (2017).	China, United States of America, Sweden	big data, cyber-physical systems, Industry 4.0, intelligent manufacturing, preventive maintenance.	manufacturing applications of big data solution for active preventive maintenance
Sikorski, J. J., Haughton, J., & Kraft, M. (2017).	United Kingdom, Singapore	blockchain technology,chemical industry, electricity market,machine-to-machine communications	blockchain technology in chemical industry and its applications in machine-machine interaction
Liao, Y., Deschamps, F., Loures, E. de F. R., & Ramos, L. F. P. (2017).	Brazil	the fourth Industrial revolution; Industry 4.0; systematic literature review; qualitative research; quantitative research; research agenda	the past, present and future of Industry 4.0 - a systematic literature review
Theorin, A., Bengtsson, K., Provost, J., Lieder, M., Johnsson, C., Lundholm, T., & Lennartson, B. (2017).	Sweden	automation; agile manufacturing; manufacturing information systems; service-oriented manufacturing systems, event-driven architecture	developing event-based manufacturing information system architecture for Industry 4.0
Wan, J., Tang, S., Shu, Z., Li, D., Wang, S., Imran, M., & Vasilakos, A. (2016).	China Saudi Arabia Sweden	Industry 4.0, industrial wireless networks, industrial Internet of Things, software-defined networks, cyber physical systems.	software-defined industrial internet of things in the context of Industry 4.0
Wang, S., Wan, J., Zhang, D., Li, D., & Zhang, C. (2016).	China	Industry 4.0,smart factory,cyber-physical system,multi-agent system, deadlock prevention	evaluation of smart factories in the context of Industry 4.0
Zhan, Z.-H., Liu, X.-F., Gong, Y.-J., Zhang, J., Chung, H. S.-H., & Li, Y. (2015).	China United Kingdom	cloud computing, resource scheduling, evolutionary computation, genetic algorithm, ant colony optimization, particle swarm optimization	evolutionary approaches in cloud computing resource planning