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- RESEARCH ARTICLE –

Industry 4.0 During Pandemic

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Abstract

Covid-19 has been a pandemic with a global impact both on the world economy and on the survival of business enterprises. As the production has become digitalized and smarter, Industry 4.0 has also become a necessity for the industries. The term refers to the fourth industrial revolution in which the life cycle of the products has a new organizational and control level on the whole value chain, and it is for personalized customer needs. Industry 4.0 is not only a visionary but also a realistic concept with the introduction of the internet of things, industrial internet, smart manufacturing and cloud-based manufacturing process. Even though Covid-19 has a destructive impact, it also initiated a series of change in digital transformation. Covid-19 rapidly shapes digitalization between the sectors as well as the global business ecosystem, which creates a new opportunity for the digital leaders to discover innovative digital strategies and applications to direct their corporate digital transformation. The purpose of this article is to study the new trends and workflows in business enterprises while carrying out new technological applications of Industry 4.0 during Covid-19 pandemic.

Key Words: Covid-19, Industry 4.0, Business, Technology, Digitalization.
Jel Kodes:M0, M1, O0, O30

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Pandemi Sürecinde Endüstri 4.0

Özet

Covid-19 salgını tüm dünyayı etkisi altına alırken, bir yandan dünya ekonomisi bir yandan işletmeler hayatta kalmak için mücadele etmektedir. Üretim sürecinin dijitalleşmesi ve akıllı hale gelmesiyle Endüstri 4.0 endüstrilerin bir gereksinimi olmuştur. Endüstri 4.0 terimi, ürünlerin yaşam döngüsünün tüm değer zinciri üzerinde yeni bir organizasyon ve kontrol düzeyi olarak tanımlanan dördüncü sanayi devrimi anlamına gelir ve kişiselleştirilmiş müşteri gereksinimlerine yöneliktir. Endüstri 4.0 vizyoner olmakla birlikte, nesnelerin interneti, endüstriyel internet, akıllı üretim ve bulut tabanlı üretimi içeren, gerçekçi bir konseptir. Endüstri 4.0 sürekli iyileştirme sağlamak ve katma değer yaratan faaliyetlere ve israfı önlemeye odaklanmak için üretim sürecinde işletmelerin sıkı entegrasyonuyla ilgilidir. Bu makalenin amacı, Covid-19 sürecinde, işletmelerin Endüstri 4.0'ın yeni teknolojik uygulamalarında ortaya çıkan yeni eğilimleri ve akışları incelemektir.

Anahtar Kelimeler: Covid-19, Endüstri 4.0, İşletme, Teknoloji, Dijitalleşme.
Jel Kodları:M0, M1, O0, O30

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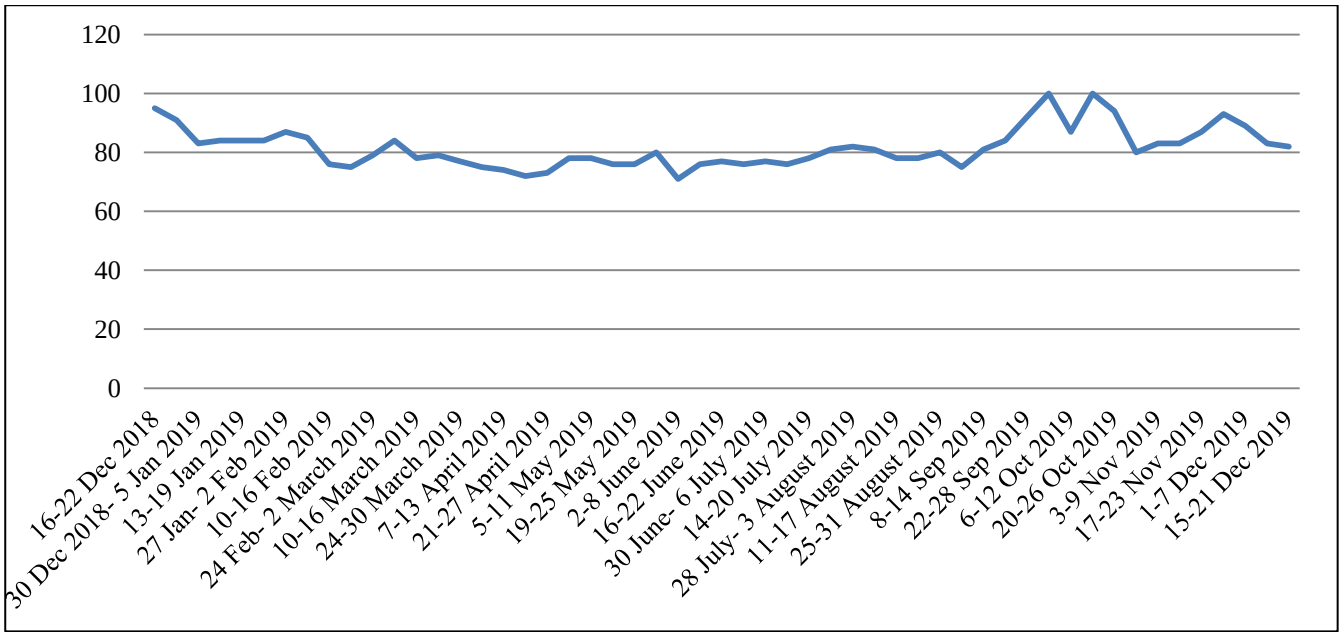
Introduction

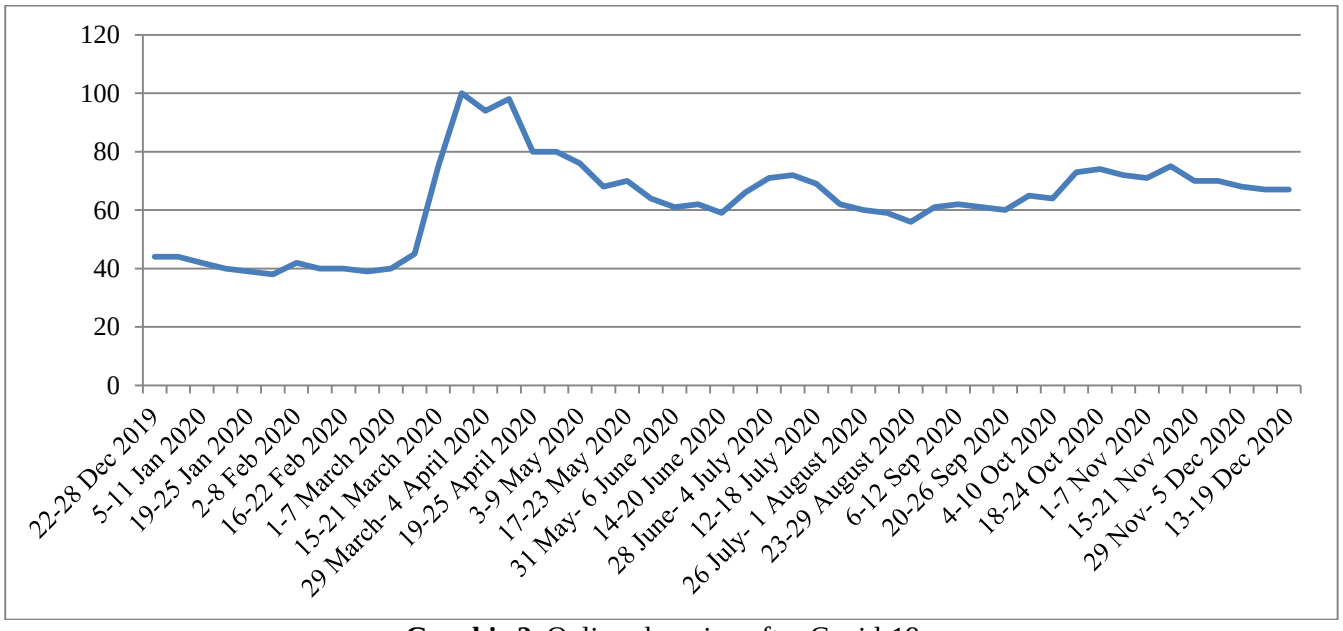
Covid-19 has made it inevitable for the businesses to modify their future strategies all around the world. Customers prioritize online shopping, as a result. While some businesses go through a period of increase in demand; others are on the verge of closing. Yet, with its smart technologies, Industry 4.0 can offer viable options to make businesses strong and agile.

Industry 4.0 has recently been a controversial topic. Some researchers discuss on which stage of technology we are while there are others who consider the introduction of digital technologies (IoT, virtual reality, mixed reality, augmented reality, wearable technologies) as a fifth revolution concentrating on know-how and technology. The quest of innovation and an innovation-based company culture are indispensable for the companies pursuing sustainable leadership (Yazıcı, 2020). Besides, businesses are required to introduce a new perspective into the future of human labour based on new leadership styles during Industry 4.0 (Akkaya and Yazıcı, 2020).



Graphic 1. Online shopping before Covid-19

Source: (Google Trends, 2020). https://trends.google.com/trends/explore?date=today%205-y&q=online%20shopping



Graphic 2. Online shopping after Covid-19

Source: (Google Trends, 2020). https://trends.google.com/trends/explore?q=online%20shopping

Since the first industrial revolution, there have been some radical changes in the production varying from machinery powered by water and steam to electrical and digital automatic production. Production stages have become more and more complicated, automatic and sustainable ever since. This means that people can operate machinery in a simple, efficient and durable way (Qin, Liu and Grosvenor, 2016). It wasn't until the mid-1990s when the mobile and internet technologies started to be produced, eventually leading to a transformation in both production and consumption types due to cyber-physical systems (Şen, 2020) and enabling an effective and efficient management of the complex production structure in a cyber-physical environment (Şen and İrge, 2020).

Industry 4.0 means a breakthrough radically forcing traditional industries to change themselves. Of all the current and future challenges, few examples include the enhanced complexity of product and process, volatile markets and shortened cycles of product, market, technology and innovation. The concept of Industry 4.0 is considered as a significant strategy to preserve competitive power in the future. In addition to competitive products and services, it also includes designing and applying administrative, strong, flexible logistics and production systems (Rennung, Luminosu and Draghici, 2016).

Industry 4.0, a German initiative on strategy, aims at creating smart factories in which the production technologies are transcended and transformed by cyber-physical systems, internet of things and cloud computing. In the age of Industry 4.0, production systems can be followed by physical processes to create a so-called digital twin of the physical world, to make smart decisions through real time communication and cooperation with men. In addition to being integrated into the business and manufacturing processes; Industry 4.0 also combines internal technologies of the manufacturing with smart manufacturing processes to pave the way for a more technologic era through a radical change in the value chains and business models (Zhong, Xu, Xun and Klotz & Newman, 2017).

The notion of Industrial Internet was initially brought to the agenda by General Electric in 2012. Integrating big data analytics and IoT to unite the physical and the virtual worlds; this concept includes a range of business fields varying from energy production, health, production, public sector, transportation and mining. It has been assumed by the Industrial Internet Consortium that 46% of the global economy including General Electrics and some other companies will make use of this concept (Rojko, 2017). In 2013, the second phase of re-industrialization plan in France started with a movement called "Industrie du futur". The main objective of this plan is to remove the boundaries between industry and services and thus to create more private manufacturing methods, business models and organization structure in the new digital world (Ministére De L'europe Et Des Affaires Etrangéres, 2015). Five steps of Industrie du futur includes 1) additive manufacturing, virtual facility, internet of things, augmented reality 2) new technologies to support adjustments for small and medium size enterprises 3) employee training 4) enhanced international cooperation on industrial standards and 5) incentives on future French industries (Rojko, 2017).

Industry 4.0 is made up of advanced analytics, automation, network connection and advanced product technologies. Industry 4.0 technologies had already started to improve the transition of operations in enterprises to add more values even before Covid-19 hit the world and it gained even more importance soon when people were forced to avoid any close contact during the pandemic. Industry 4.0 seems to have a promising future particularly at times of business crises, depending on the need for digitized procedures for workplace flexibility. Players of the industry who make use of innovations brought by digitalization will be able to continue their business activities without being influenced by the changing conditions, without sacrificing quality or efficiency. Soon, business enterprises will eventually invest their capital and labour into the most urgent and the most easily applied technologies for the sustainability of their work. However, in the long run, without the limitations due to liquidity preservation, more digital solutions and investments will take place in the foundation of businesses in order to transform the business for better efficiency along the value chain (Boni Global, 2020).

1. INDUSTRY 4.0

Industry is an extremely mechanized, automatic part of economy producing material (Lasi, Fettke, Kemper and Feld & Hoffman, 2014). It was the technical advancement that triggered the first three industrial revolutions. The first one was initiated when a mechanical manufacturing facility was established with the use of waterpower and steam power. The second one started with the introduction of electric powered mass production based on work division. And the third one began when advanced electronics and information technologies were introduced into production automation (Brettel, Friederichsen and Keller & Rosenberg, 2017).

These notions combining cyber physical systems, internet of things and internet of services started a fourth industrial revolution after the third one (HuanSheng and Hong, 2015). Unlike previous ones, the fourth industrial revolution is not only between man and man or man or machinery but also between man and machinery (Cooper and James, 2009). Industry 4.0 is all about making things smarter by making products order machinery what to do. Barcodes and RFID chips are read online by a scanner or a computer so that machinery can connect to the smart things. This is how they work (Sommer, 2015).

Emerged when machinery started to manage themselves and the production process without the need for manpower; Industry 4.0 was originally considered a technology trial. Now, it has become a prerequisite to preserve competition in a constantly changing industrial environment (Yıldız, 2018).

Through a factory-based digitalization; Industry 4.0 is a combination of smart things, internet technologies and future technologies and it will create a new paradigm in industrial production (Lasi, Fettke, Kemper and Feld & Hoffman, 2014).

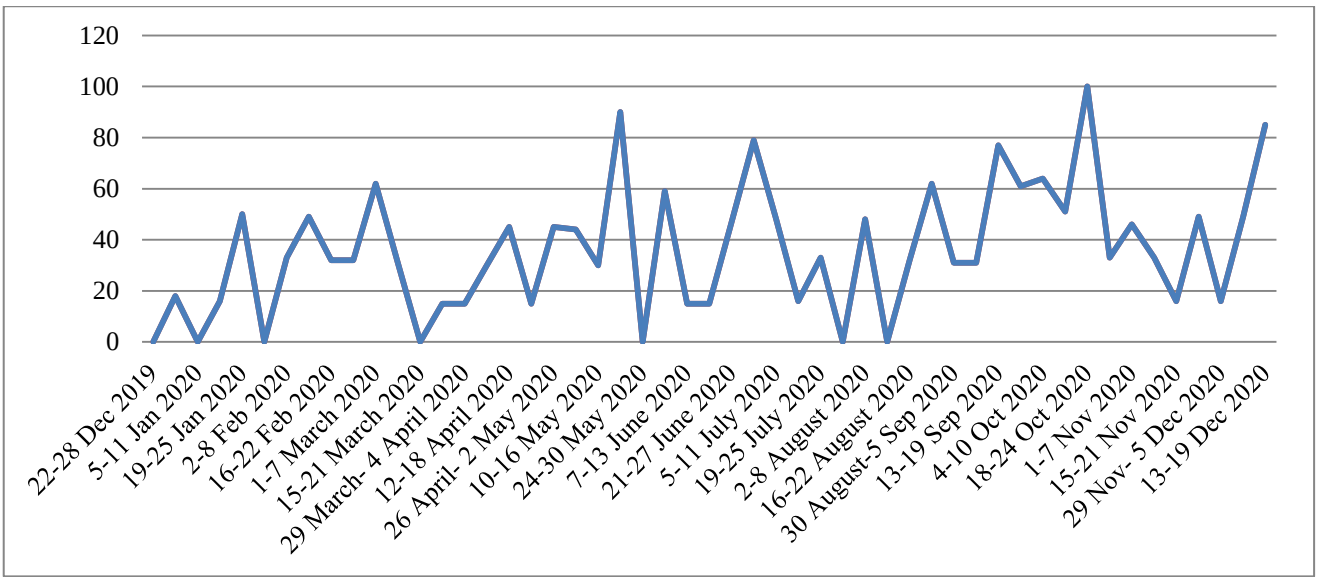
Industry 4.0 paradigm is when the physical elements connect to each other and to the internet. Data collected and produced by information communication technology systems and sensors should be presented in a way to give an immediate response to the possible problems and shortages so that the manufacturing process can speed up. Moreover, existing information communication designed to support the initial production process imposes the development of conceptual difference for current information distribution systems and thus fails to provide accurate information when needed (Sipsas, Alexopoulos and Xanthakis & Chryssolouris, 2016).

Germany and China are the prominent countries when it comes to producing and applying the most competitive and advanced technologies for Industry 4.0. For instance, Germany had advanced manufacturing companies and factories. In addition to its ability to manage complex industrial processes, it has the capacity to make use of its competitive and advanced technological power by making different partnerships in different geographies (Kagermann, Wahlster and Helbig, 2013). German government invests significantly in Research and Development to ensure the development of industry (Qin, Liu and Grosvenor, 2016). The number of robots sold in Germany, the fifth largest robot market in the world and the largest one in Europe, increased 26% and became 27.000 in 2018 (IFR, 2020).

In 2015, industrial growth plan 'Made in China 2025' was introduced in China. The main objective of this initiative is to be inspired by Germany's Industry 4.0 concept and adapt it to China's needs so that China's industry can grow. This transformed manufacturing should be sustainable, and innovation focused. This initiative plan determined ten sectors made up of team workshops in robotics, automatics and information technology. China's long-term goals include a reformation in its manufacturing industry and a transition from low-cost products to high quality products. Another long-term goal of China is to take over Germany's and Japan's dominance by 2035 and to transform into a superpower for the industrial world in 2049 (Zhong, Xu, Xun and Klotz & Newman, 2017). In order to enhance the life quality, the sector needs to keep up with the new technologies brought by Industry 4.0. Sector. The sector can provide the society with personalized high-quality products, a better working environment for the employees so that it can enhance welfare and life standards. However, this product paradigm is not sustainable. Industrial manufacturing has certainly some negative impacts on global warming and environmental pollution as it consumes a significant amount of unrenewable resources such as oil and coal. As the population grows older and the workforce decreases; the industry needs a drastic change and radical transformation. With the advent of Industry 4.0, production can be high quality, low cost, flexible, efficient and green. Still, information technologies should be used to apply these services (Wang, Wan and Li & Zhang, 2016).

2. COMPONENTSOF INDUSTRY 4.0

Today, information, communication and production technologies are in a rapid and effective change and transformation. With the effect of technological developments and digitalization, structures and systems in all areas of business and social life are updated. In this context, companies use digitalization intensively in all business processes and business models in accordance with this system (İrge and Şen, 2020).



Graphic 3. Use of digital technology

Source: (Google Trends, 2020).https://trends.google.com/trends/explore?q=use%20of%20digital%20technologies

Industry 4.0 is the future of global production. Recent digital systems emerging as an integral part of Industry 4.0 can measure the data from both physical and digital resources. Industry 4.0 has nine components. These are Internet of Things, Big Data, Cloud Computing, Augmented Reality, Cyber-Physical System, Autonomous Robots, Additive Manufacturing (3-D Printing), Simulation and Internet of Services and these components are explained below.

2.1. Internet of things

Suggested by Weiser in the early 1990s, the internet of things is based on the concept of 'computing anytime anywhere'(Ercan and Kutay, 2016). Internet of things has a profound potential to change our interaction with our environment and it makes it possible to electronically monitor and control the objects in the physical world. Internet of things has such benefits as increasing the time saving and quality of life between people and enterprises by optimizing the performance of the systems and processes (McKinsey&Company, 2015). Internet of things is characterized by a combination of physical and digital compounds to create innovation, innovative products and new business models. Thanks to increasingly efficient power management, reliable memory, broadband communication and micro processing technologies; it will be possible to digitalize the functions of industrial products and their fundamental abilities (Wortmann and Flüchter, 2015). The internet of things can be seen in various areas such as smart systems, smart communication, smart buildings, smart homes, smart production and smart cities (Dengiz, 2017).

2.2. Big data

The term 'big data' means storing, transferring, improving, analysing, searching, visualizing, confidentiality and security (Da Xu and Duan, 2019). Big data is based on the analysis of broad band data and is one of the most trending concepts in this era. Advancement in computer and memory systems has made it possible to collect and store an unprecedented amount of data. Cyber-physical systems and internet of things allows the transfer of immense data into physical systems (Wang, Kung and Ting & Byrd, 2015). Such systems as big data lessen the need for the number of servers, and they make it easier to access the information required for the manufacturing process. Furthermore, big data systems ensure public visibility of the information. In so doing, it ensures a cost advantage for the companies and a low-cost advantage for the consumers (Alçın, 2016).

2.3. Cloud computing

Cloud computing is a technology allowing the storage of all data in a virtual cloud accessible online upon request (Annaç Göv and Erdoğan, 2020). According to the US National Institute of Standards and Technology (NIST); cloud computing is defined as " an easily accessible and easily marketable model with minimum management effort or cloud provider interaction to activate on-demand networks in line with the shared pool of information in configurable technology resources " (Butt, 2020:15). In the cloud computing model, there is the co-existence of certain services in a singular or multiple way so that the user can be provided with an adjustable flexibility within the service. These services (formed and presented in a single form or in different forms if

needed) can be listed respectively as Software as a Service, Platform as a Service, Infrastructure and Cloud computing and Any Service (Şahin, Bovkır and Aydınoğlu, 2020).

2.4. Augmented reality

Augmented Reality is a recent technology which reflects computer graphics on real world images (Azuma, 1997). Predetermined targets are linked with virtual objects upon being captured; and then interpreted as outcomes through augmented reality technology programmes (Yılmaz and Göktaş, 2018). Majority of current augmented reality use usually aims at commercial and industrial areas. According to Golden Sachs estimates, they have the greatest market potential in the business segment. As a result, these applications are used as pilot projects to evaluate both their integration into current business applications and their feasibility in the real world(Jackl, Schöffer and Husinsky & Wagner, 2018).

The use of Augmented Reality in the industry is considered important as it contributes significantly to the communication process within the product design and manufacturing. It helps determine and avoid the design failures during the initial phases of the development process. It lessens down the number of physical prototypes and thus saves both time and the cost. Augmented Reality is regarded as a valuable tool to improve and to accelerate products and processes in several industrial applications (De Pace, Manuri and Sanna, 2018).

2.5. Cyber-physical system

Cyber-Physical Systems comprise a combination of computing, communication and control with the physical processes in such areas as mechanics, electrics and chemistry. The interaction between the physical world and the intelligence provided by distributed and interdependent processes has become important. There are many researchers, practitioners and national academy institutes who have their own definition and understanding for cyber-physical systems. Within cyber physical systems where embedded computers and networks control and monitor physical processes including feedback cycles with an impact on the computation of physical processes. In order to design these systems, it is therefore necessary to understand the dynamics shared within the computers, software, networks and physical processes (Boulila, 2019).

2.6. Autonomous robots

The first industrial application of smart robots put forward the great possibilities production automation may offer. Due to a flexible microprocessor control; robotic industries and robotic technologies give the business enterprises a new look. Industry 4.0 will change the manufacturing; yet it will also transform the half-robotic products for the industrial and research applications. These advanced machines can constantly decrease the operational and production costs for the companies and can help the business enterprises accelerate the digital transformation they might require for improving their innovations and qualities. This insight predicts that robots and sensors will be fundamental to data based design approach and the lifelong connectivity between the product and the producer, future tightness and malfunctions in digital factories, interconnected machineries which can sense and predict (Avishay, Pavlov, Pavlova and Petrov & Dimitrov, 2019).

The idea of Industry 4.0 paradigm is that an industrial robot can be cooperative and serve as an assistant for the people working in the production. The main element of the paradigm is artificial intelligence based on the internet of things. Cooperative robotics and innovation transform the business process in the modern industry. Integrating robots into production will contribute to computerization and automation, which generally lead to an understanding of a concept called smart manufacturing (Galin and Meshcheryakov, 2019).

2.7. Additive manufacturing (3-d printing)

3-D printing is an additive manufacturing system made up of melted thin layers placed one upon the other to create a physical object from a digital design (Chong, Pan, Chin, Show and Yang & Huang, 2018; Soylu, 2018). The use of 3-D technology in Industry 4.0 will have a determining role in diminishing the process efficiency and complexity. 3-D technology can be used to create a rapid prototype and thus will create opportunities for the processes of production with a high level of decentralism (Horst, Duvoisin and De Almeida Vieira, 2018).

2.8. Simulation

Nowadays, 3-D simulations of products, materials and manufacturing processes are being used in the engineering phase. However, in the future, simulations will have a much more wide-spread use in the facility operations. These simulations will make use of real time data to reflect a physical world in a virtual model where machinery, products and people may take place. Before the operators are physically transformed,

simulation allows testing and optimizing the machinery settings for the next product in the virtual world (Rüßmann, Lorenz and Gerbert & Waldner, 2015).

2.9. Internet of services

Internet of Services are based on data transfer from information technologies to make daily activities safer and easier. The internet of services is intended to provide services over the internet for business models, business partners and services depending on the type of digitalization. The internet of services is about providing an accessible communication between sellers and consumers in various ways and about bringing services together to provide additional services of value (Tay, Lee and Hamid & Ahmad, 2018).

3. INDUSTRY 4.0 and COVID-19

Before Covid-19, business leaders of Industry 4.0 focused on sustainability and innovation to get a competitive advantage and boost productivity and lower the costs. After Covid-19, business enterprises started to focus on how to survive and to mitigate the damage made by the pandemic (Czifra and Molnár, 2020). It is seen that the initial impacts of Covid-19 are on the decline and the business enterprises in some parts of the world face new pressures. This situation is likely to continue for a while. To cope with the crisis, companies should become more digital in their responses. However, as technology gets more and more adopted; the business enterprises need to become more flexible and agile against the restrictions brought by liquidity (Agrawal, Eloot and Mancini & Patel, 2020). Currently, the priorities of many businesses include survival, rescue and some regenerated works in the post-pandemic world. When a model for the businesses to define themselves is defined; the experiences obtained at the time of crisis should be taken into consideration so that a more agile and resilient business model can be established (Czifra and Molnár, 2020). Industry 4.0 and more efficient tools and methods will be needed to help mitigate the impact of any current or future pandemics on the abilities of the employees in the virtual world. In such times of crisis, some factors needed to be used to boost resilience and new technologies brought by Industry 4.0 should be rapidly used. These include (Cognizant, 2020):

a) Accelerating virtual working space: Businesses can adopt virtual workplaces and use an integration platform to combine data coming from these systems so that they can create details of the job done and create a real time image. This factor will ensure quicker and more robust decisions for raw materials, shipments and employees.
b) Extending block chain and additive manufacturing networks: In order to operate through the virtual networks of local manufacturers and small suppliers with a matured integration; it may be easier to use smart contracts distributed through the block chain. This will make it easier to accept the mindset that innovation and product design is an intellectual property for the enterprise.
c) Distributing sensors and devices operation on the internet of things: Recently, the internet of things transforms each device - as well as every single component in that device - into a data maker. A comprehensive use of sensor technology will make the operations whole again by removing the blind spots, monitoring management or visualization systems, by making operations remotely operated. Data received will be integrated into business and engineering systems for the purpose of analysis and such management systems will be able to predict any breakdown in the assembly line.
d) Using artificial intelligence and augmented reality: Sticking to social distance rules, the employers working in the manufacturing should increase their capacity to use virtual reality and augmented reality. For instance, when a problem occurs during distance working, experts can remotely connect to the device with an augmented reality headphone or hologram technique to solve the problem as soon as possible.
e) Remote video surveillance: Experts working in the virtual environment can be stimulated by video analytics and the internet of things so that they can examine a process station, identify the problems or guide on-site maintenance. This technology can also be used for distant visual inspections. The high capacity, speed and low delay period seen offered by the new 5G wireless networks will make it possible to transfer video data to a local cloud endpoint for quick analysis.

Smart sensors, 3-D printing, nanotechnology, biotechnology, quantum, cloud computing, internet of things, block chain, big data and artificial intelligence are all the keystones in Industry 4.0 revolution. They are all connected to each other. However, the Industry 4.0 revolution is just in its initial phase and it requires many more stages to overcome certain problems such as the start-up cost. Variability in the materials produced is rather a technical issue and there must be regular post production controls to evaluate whether the product is working or not (Bragazzi, 2020).

4. CONCLUSION

When pre-Covid and post-Covid periods are taken into consideration; it is seen that the whole world is in a state of tremendous change. Millions of people socially distancing each other and following the rules of lockdown, adjusting the working hours in accordance with the lockdown restrictions have all caused a radical transformation in the global workflow. While there have been some dramatic events slowing down certain trends during the pandemic; there have also been others accelerating them. Before Covid-19, the business enterprises primarily put an emphasis on cost reduction, competitive advantage, sustainability and innovation. However, with the advent of this global pandemic, business enterprises started to focus on how to survive and to sustain their business.

Businesses have come across with a series of challenges in the manufacturing line during Covid-19. Industry 4.0 is production focused and it offers low cost and quality products to the customer in a quicker way. Therefore, businesses are supposed to adopt the changes brought by Industry 4.0 in order to create a competitive advantage, innovation and sustainability. Due to digitalization and automation; competitive strategies based on cheap and unqualified labour are no longer valid.

When industrial revolutions are studied, it is seen that a great technology transformation takes place after every revolution. The digital age in which we live is a living proof of it. Undoubtedly, against the challenges brought by Covid-19, business enterprises should rapidly follow and adapt to trends in order to popularize automation and Industry 4.0 applications. In so doing, business enterprises will have a capacity to discover the potential of Industry 4.0, to digitalize in creating new business and to create solutions offering new opportunities.

REFERENCES

Agrawal, M., Eloot, K., Mancini, M., & Patel, A. (29 Temmuz 2020). Industry 4.0: Reimagining manufacturing operations after COVID-19. https://www.mckinsey.com/business-functions/operations/our-insights/industry-40-reimagining-manufacturing-operations-after-covid-19. (02.10.2020).

Akkaya, B., & Yazıcı, A. M. (2020). Comparing Agile Leadership With Biomimicry-Based Gray Wolf: Proposing A New Model. *Business & Management Studies: An International Journal*, 8(2), 1455-1478. https://doi.org/10.15295/bmij.v8i2.1480

Alçın, S. (2016). Üretim için yeni bir izlek: Sanayi 4.0. *Journal of Life Economics*, Cilt 3, Sayı 2, 19-30. https://doi.org/10.15637/jlecon.129

Annaç Göv, S., & Erdoğan, D. (2020). Dördüncü Endüstri Devriminin (Endüstri 4.0) Neresindeyiz?. *İstanbul Gelişim Üniversitesi Sosyal Bilimler Dergisi*, 7(2), 299-318. DOI: https://dx.doi.org/10.17336/igusbd.661236

Avishay, D., Pavlov, V., Pavlova, G., Petrov, B., & Dimitrov, N. (2019). Industry 4.0- Robots with Distributed Mobility and Elements of AI. *Global Journal of Computer Science and Technology: D Neural & Artificial Intelligence*, Volume 19, Issue 1.

Azuma, R. (1997). A survey of augmented reality. *Teleoperators and Virtual Environments*, 6, 4, 355-385.

Boni Global. (27 Ağustos, 2020). Post Covid-19 Dünyasında Endüstri 4.0'ın Geleceği. https://www.boniglobal.com/tr/the-future-of-industry-4-0-in-the-post-covid-19-world/ (02.10.2020).

Boulila, N. (2019). Cyber- Physical Systems and Industry 4.0: Properties, Structure, Communication, and Behavior. *Technical Report*, DOI:10.13140/RG.2.2.27890.76485

Bragazzi, N. L. (2020). Digital Technologies-Enabled Smart Manufacturing and Industry 4.0 in the Post-COVID-19 Era: Lessons Learnt from a Pandemic. *Int. J. Environ. Res. Public Health*, 17, 4785; doi:10.3390/ijerph17134785

Brettel, M., Friederichsen, N., Keller, M., & Rosenberg, M. (2017). How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective, World Academy of Science, Engineering and Technology. *International Journal of Information and Communication Engineering*, V.8, N.1.

Butt, J. (2020). Exploring The Interrelationship Between Additive Manufacturing and Industry 4.0. *Designs*, 4, 13. doi:10.3390/designs4020013

Chong, S., Pan, G. T., Chin, J., Show, P. L., Yang, T. C. K., & Huang, C. M. (2018). Integration of 3D Printing and Industry 4.0 into Engineering Teaching. *Sustainability*, 10, 3960. doi:10.3390/su10113960

Cognizant. (24 April 2020). COVID-19: Accelerating Industry 4.0: A Good Prescription for Surviving Today's Pandemic and Mitigating the Next One. https://www.cognizant.com/perspectives/covid-19-accelerating-industry-4-0-a-good-prescription-for-surviving-todays-pandemic-and-mitigating-the-next-one. (02.10.2020).

Cooper, J., & James, A. (2009). Challenges for database management in the Internet of things. *IETE Technical Review*, 26, 320- 329. doi:10.4103/0256-4602.55275

Czifra, G., & Molmár, Z. (2020). Covid-19 and Industry 4.0. *Sciendo*, Volume 28, Number 46. DOI:10.2478/rput-2020-0005.

Da Xu, L., & Duan, L. (2019). Big data for cyber physical systems in industry 4.0: a survey. *Enterprise Information System*, 13:2, 148-169. DOI: 10.1080/7517575.2018.1442934

Dengiz, O. (2017). Endüstri 4.0: Üretimde Kavram ve Algı Devrimi. *Makine Tasarım ve İmalat Dergisi*, Volume 15, Issue, 1, 38-45.

De Pace, F., Manuri, F., & Sanna, A. (2018). Augmented Reality in Industry 4.0. *Am J Compt Sci Inform Technol*, Vol.6 No.1:17.doi: 10.21767/2349-3917.100017

Ercan, T., & Kutay, M. (2016). Endüstride Nesnelerin İnterneti (IoT) Uygulamaları. *AKÜ FEMÜBİD*, 16, 035102, 599-607. DOI:10.5578/fmbd.43411

Galin, R., & Meshcheryakov, R. (2019). Automation and robotics in the context of Industry 4.0: the shift to collaborative robots. *IOP Conf. Series: Materials Science and Engineering*, 537, 032073. doi:10.1088/1757-899X/537/3/032073

Horst, D. J., Duvoisin, C. A., & De Almeida Vieira, R. (2018). Additive Manufacturing at Industry 4.0: a Review. *International Journal of Engineering and Technical Research (IJETR)*, Volume 8, Issue 8.

HuanSheng, N., & Hong, L. (2015). Cyber-physical-social-thinking space based science and technology framework for the Internet of Things. *Sci. China Inf. Sci*. 58, 1-19. https://doi.org/10.1007/s11432-014-5209-2

International Federation of Robotics. (2020). Industrial Robots: Robot Investment Reaches Record 16.5 billion USD. https://ifr.org/ifr-press-releases/news/robot-investment-reaches-record-16.5-billion-usd (28.09.2020).

İrge, N. T., & Şen, E. (2020). Çalışanların Dijital Teknolojiye Yönelik Tutumlarının ve İç Girişimcilik Özelliklerinin Bireysel İş Performanslarına Etkisi. İşletme Araştırmaları Dergisi, 12(3), 2556-2579 https://doi.org/10.20491/isarder.2020.993

Jackl, A., Schöffer, L., Husinsky, M., & Wagner, M. (2018). Augmented Reality for Industry 4.0: Architecture and User Experience. *11th Forum Media Technology*, St. Pölten, Austria

Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative Industrie 4.0, Industrie 4.0 Working Group. *acatech – National Academy of Science and Engineering*.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffman, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, 6, 239-242. DOI: 10.1007/s12599-014-0334-4.

McKinsey & Company. (2015). The Internet of Things: Mapping The Value Beyond The Hype. https://www.mckinsey.com/~/media/McKinsey/Industries/Technology%20Media%20and%20Telecommunications/High%20Tech/Our%20Insights/The%20Internet%20of%20Things%20The%20value%20of%20digitizing%20the%20physical%20world/Unlocking_the_potential_of_the_Internet_of_Things_Executive_summary.pdf (05.10.2020).

Ministére De L'europe Et Des Affaires Etrangéres. (2015). Industry of the future. http://www.ambafrance-de.org/Vorstellung-des-neuen-franzosischen-PlansIndustrie-du-Futur-in-der-Botschaft. (28.09.2020).

Rennung, F., Luminosu, C. T., & Draghici, A. (2016). Service Provision in the Framework of Industry 4.0. *Procedia- Social and Behavioral Sciences*, 221, 372-377. Doi:10.1016/j.sbspro.2016.05.127.

Rojko, A. (2017). Industry 4.0 Concept: Background and Overview. *IJIM*, Vol.11, No.5. https://doi.org/10.3991/ijim.v11:5.7072.

Rüβmann, M., Lorenz, M., Gerbert, P., & Waldner, M. (April 09, 2015). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. *The Boston Consulting Group*.

Sipsas, K., Alexopoulos, K., Xanthakis, V., & Chryssolouris, G. (2016). Collaborative maintenance in flow-line manufacturing environments: An Industry 4.0 approach. 5th CIRP Global Web Conference Research and Innovation for Future Production, *Procedia CIRP*, 55, 236-241. Doi:10.1016/j.procir.2016.09.013.

Sommer, L. (2015). Industrial revolution—Industry 4.0: Are German manufacturing SMEs the first victims of this revolution?. *Journal of Industrial Engineering and Management*, 8, 1512-1532. doi:10.3926/jiem.1470

Soylu, A. (2018). Endüstri 4.0 ve Girişimcilikte Yeni Yaklaşımlar. *Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, Sayı 32, 43-57. DOI: 10.30794/pausbed.424955

Şahin, E. K., Bovkır, R., & Aydınoğlu, A. Ç. (2020). Yeni Teknolojik Gelişmelerin Coğrafi Bilgi Sistemlerine Etkisi. *Harita Dergisi*, 163, 1-16.

Şen, E. (2020). COVID-19 Pandemik Krizinin Yönetim ve Ekonomi Politik Üzerine Olası Etkileri. *Yönetim, Ekonomi ve Pazarlama Araştırmaları Dergisi*, 4(2): 71-84. DOI:10.29226/TR1001.2020.186

Şen, E., & İrge, N. T. (2020). Industry 4.0 and Agile Firms, *Agile Business Leadership Methods for Industry 4.0*, 209-232. doi:10.1108/978-1-80043-380-920201013

Qin, J., Liu, Y., & Grosvenor, R. (2016). A Categorical Framework of Manufacturing for Industry 4.0 and Beyond. *Procedia CIRP*, 52, 173-178.

Wang, Y. C., Kung, L. A., Ting, C., & Byrd, T. A. (2015). Beyond a Technical Perspective: Understanding Big Data Capabilities in Health Care. *48th Annual Hawaii International Conference on System Sciences(HICSS)*, At: Kauai, Hawaii. DOI: 10.1109/HICSS.2015.368

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing Smart Factory of Industrie 4.0: An Outlook. *Hindawi Publishing Corporation International Journal of Distributed Sensor Networks*, Volume 2016, Article ID 3159805, 10 pages http://dx.doi.org/10.1155/2016/3159805.

Wortmann, F., & Flüchter, K. (2015). Internet of Things Technology and Value Added. *Bus Inf Syst Eng*, 57(3):221–224. DOI: 10.1007/s12599-015-0383-3

Tay, S. I., Lee, T. C., Hamid, N. A. A., & Ahmad, A. N. A. (2018). An Overview of Industry 4.0: Defination, Components, and Government Initiatives. *Jour of Adv Research in Dynamical & Control Systems*, Vol 10, 14.

Yazıcı, A. M. (2020). Biomimicry and Agile Leadership in Industry 4.0, *Agile Business Leadership Methods for Industry 4*.0, 155-170. doi:10.1108/978-1-80043-380-920201010

Yıldız, A. (2018). Endüstri 4.0 ve akıllı fabrikalar. *Sakarya Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 22 (2), 546-556. Doi:10.16984/saufenbilder.321957.

Yılmaz, R. M., & Göktaş, Y. (2018). Using Augmented Reality Technology in Education. *Çukurova Üniversitesi Eğitim Fakültesi Dergisi*, 47(2), 2018, 510-537. DOI: 10.14812/cuefd.376066

Zhong, R. Y., Xu, Xun., Klotz, E., & Newman, S. T. (2017). Intelligent Manufacturing in the Context of Industry 4.0: A Review. *Engineering*, 3, 616-630. http://dx.doi.org/10.1016/J.ENG.2017.05015

https://trends.google.com/trends/explore?date=today%205-y&q=online%20shopping Accessed: 19.12.2020.

https://trends.google.com/trends/explore?q=online%20shoppingAccessed: 19.12.2020.

https://trends.google.com/trends/explore?q=use%20of%20digital%20technologiesAccessed: 19.12.2020.