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TECHNOLOGICAL TRANSFORMATION OF MANUFACTURING BY SMART FACTORY VISION: INDUSTRY 4.0

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ABSTRACT

The rapid advances of information technology in recent years have provided an unprecedented opportunity for enterprises to transform their production systems by establishing "Smart Factories" where manufacturing activities are carried out through self-managing machines without the need for human operators. Having to keep pace with this development, countries and businesses are making great efforts to adapt to Industry 4.0 strategies in order to have competitive advantage. In line with this trend, this study has two objectives. The first is to identify firms and sectors that support Industry 4.0 in the manufacturing processes of leading countries in highly competitive markets of the global economy. The second is to examine the contribution of this approach to enterprises and their manufacturing processes. These objectives will enable us to determine the primary sectors in Turkey in which the Industry 4.0 approach can be applied. To this end, several companies were selected from those operating in Turkey and in the top 15 countries (out of a total of 138) ranked by the Global Competitiveness Index Report (GCIR) published by the World Economic Forum (WEF) in 2016.The names and application areas/sectors of those that support the Industry 4.0 approach in their manufacturing processes were determined. Contributions of the Fourth Industrial Revolution applications of some of the leading companies to manufacturing processes and operations were investigated by qualitatively examining the websites of these companies using descriptive analysis technique. This study is more like a review article consisting of information and findings from different sources collected, analyzed, incorporated and evaluated. The result of the study shows that Industry 4.0 is regarded as a productive business model approach that allows each data to be collected, observed and analyzed in the manufacturing environment. It can be stated that enterprises that apply this approach also aim to achieve more cost-effective production in larger quantities with higher quality and reliability at higher speeds with at least twice the efficiency, and minimum energy use, less heat generation, and less resource and memory use.

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INTRODUCTION

Having advanced rapidly in recent years, information technology has also an impact on industrial development. Since the beginning of the industrial revolution, there have been three important stages that have resulted in a great increase in industrial productivity along with the advancing technology.

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Chronologically, these stages are; the beginning of the use of steam-powered machines in factories at the end of the 18th century, the mass production based on electric power at the beginning of the 20th century and the proliferation of automation in the industry thanks to electronics and information technologies since 1970s. Nowadays, we have been witnessing the fourth stage of the industrial revolution in which value chains are linked end-to-end through cyber-physical systems and dynamic data processing. This stage is the Fourth Industrial Revolution, also referred to as Industry 4.0 which, for the first time, came to the fore at Hannover Fair in Germany and soon attracted considerable attention. Industry 4.0 is a collective term that encompasses many modern automation systems, data exchanges and manufacturing technologies (www.endustri40.com, 2017). In this system, the product itself becomes an active component of the manufacturing process which makes it possible for companies to follow faster, smarter and more flexible processes from draft design to mass production. Not only do integrated products link the value chain of manufacturing tightly to one another but also help improve the entire production processes. New manufacturing technologies will allow goods, which can be mass-produced, to be also custom manufactured more efficiently and quickly. This will enable companies, which respond immediately to changes and produce with short lead times, to be competitive on the international market (www.otomasyondergisi.com, 2017).

Industry 4.0 can also be described as a new process in which the traditional dimension of industrial production is equipped with advanced technology, and the modern face of information age brings a whole new dimension to the production process (www.inovasyon.org, 2017). This new process involves a structure which will completely transform the relations of production and consumption. Production systems, on the one hand, that instantly adapt to the changing needs of consumers, and automation systems, on the other hand, which are in constant communication and coordination with one another depict the characteristic structure of the new period in which we are entering (Alçın, 2016). In the face of changing consumer behavior and of demand for specialized products, the success of a business depends on manufacturing specialized and differentiated products in the same manufacturing process. It is anticipated that a manufacturing process using robots in smart factories will begin in the industry age requiring the development ofefficient analyses which will render manufacturing more productive in line with the data collected from customers and suppliers (www.moment-expo.com, 2017).

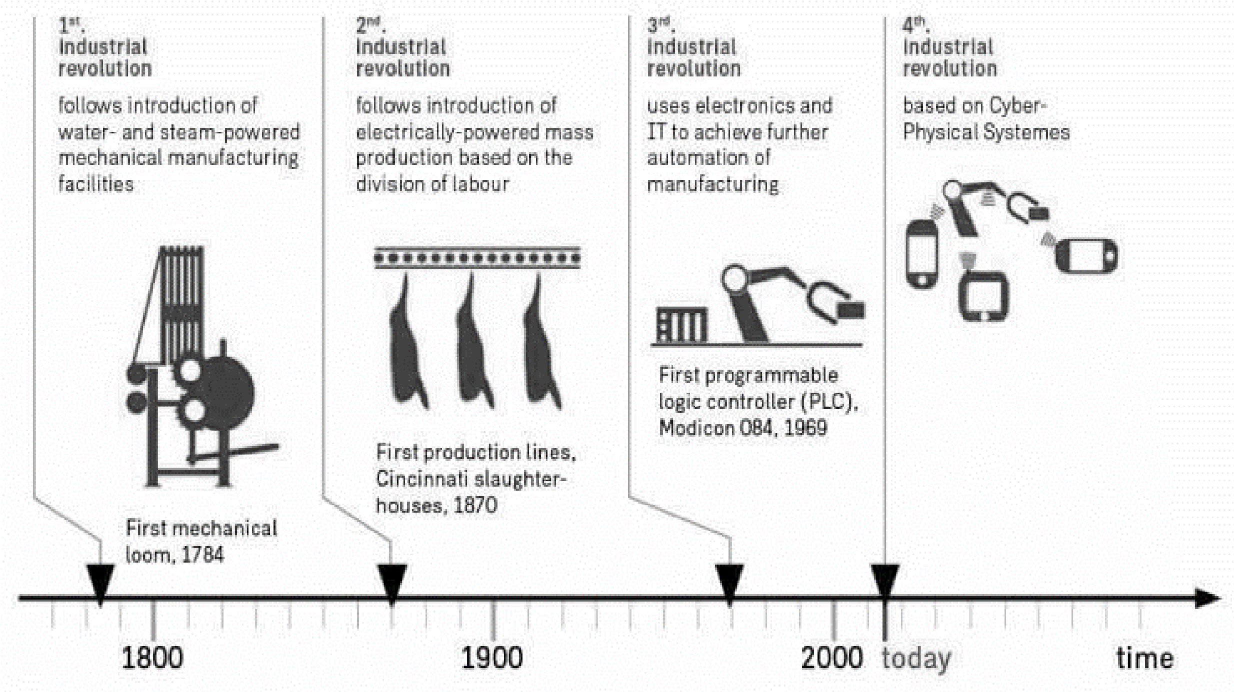
It is of utmost importance for enterprises wishing to compete effectively in today's intensifying global competition to integrate Industry 4.0 into their manufacturing processes and operations. Therefore, this study has two objectives. The first is to identify firms and sectors of leading countries that support Industry 4.0 in manufacturing processes in highly competitive markets of the global economy. The second is to demonstrate the contribution of this approach to operations and manufacturing processes. These two objectives will provide us with information to determine the primary sectors of Turkey in which Industry 4.0 can be implemented. For this purpose, the Global Competitiveness Index Report (GCIR) published in 2016 by the World Economic Forum (WEF) was used to determine the leading countries in the global competition. There are 138 countries in the report. Enterprises included in the study were selected from those operating in Turkey and in the top 15 countries, which are Switzerland, Singapore, the United States, Netherlands, Germany, Sweden, the United Kingdom, Japan, Hong Kong SAR, Finland, Norway, Denmark, New Zealand, Taiwan-China and Canada. The websites of enterprises operating in Turkey and in the top 15 countries were examined, and the names and application areas/sectors of those that support the Industry 4.0 approach in operations and manufacturing processes were determined. Siemens, Bosch, General Electric, Festo and Mitsubishi are some of the enterprises that pioneer Industry 4.0. The websites of these enterprises were analyzed using descriptive analysis technique and the contribution of their exemplary Industry 4.0 applications to manufacturing processes and operations was evaluated. For this purpose, firstly, information on the stages of the industrial revolution and on Industry 4.0 was presented. Secondly, technological factors that have triggered Industry 4.0 and their contribution to the production process and Industry 4.0 design principles was addressed. Finally, opportunities for businesses and contributions to the country's economy offered by Industry 4.0 applications were evaluated by presenting examples from the sectors in which Industry 4.0 is applied in the world and Turkey. In this way, Industry 4.0 applications of leading technology companies of the strongest countries in the global competition were investigated in order to offer insight into the subject in question and elicit information for the applicability of Industry 4.0 in the sectors in Turkey.

STAGES OF INDUSTRIAL REVOLUTION

There have been three major industrial revolutions that radically changed the production processes throughout history. Today, the production processes have set sail for a new industrial revolution referred to as Industry 4.0. Figure 1 presents the technological transformations, in terms of their characteristics, which have taken place in the industrial revolution since the end of the 18th century.

The First Industrial Revolution began with the discovery of the first mechanical weaving looms that enabled the use of water and steam power more efficiently at the end of the 18th century. This process is regarded as the evolution of production from human workforce towards machine power. The machines at the time of the first industrial revolution consisted of simple mechanical tools such as gears, pistons, belts and pulleys (Ayvaz et al., 2010). Having begun in the UK and soon made rapid progress in a short span of time, this industrial revolution spread all over Europe and the USA. The number of manufactured products in Europe greatly increased in this period owing to the acceleration of the machinery manufacturing process in the factories with the radical transformation in the structure of manufacturing. Therefore, European enterprises started searching for new markets to commercialize their products. The first industrial revolution has been one of the important steps in the way of the world becoming a "smaller and more integrated" place (cdn.endustri40.com, 2017). The cheap steel manufacturing method invented in 1860 by the British scientist, Bessemer, is considered the cornerstone of the

Second Industrial Revolution: Also referred to as the technology revolution. Having gained momentum in the late 19th and early 20th centuries, the second industrial revolution, made it possible to mass-produce owing to electricity and assembly lines (Schwab, 2016, p.16). The mechanized manufacturing in the first industrial revolution gave way to the division of labor and mass production capability in manufacturing in the second industrial revolution. One of the most recognizable and striking examples of mass production is Henry Ford's Ford Motor Company. The use of the "assembly line" technique launched by Ford in 1913 also substantially increased manufacturing in other sectors which adopted this technique (Kagermann et al., 2013). In addition to electricity and steel manufacturing, steam, coal, iron, petroleum and chemical materials also started to be used in the production process in this period which resulted in further development of the industry.



Source: www.muhendisbeyinler.net, 2017

Figure 1. Four Stages of Industrial Revolution

The Third Industrial Revolution: Started in the 1970s when mechanical and electrical technologies were replaced by digital technology. In this period, the first programmable automation systems were introduced with the advance of information, communication and electronic technologies leading to the stage of full automation of manufacturing. This industrial revolution is slightly different in quality from the first two. Having been the common means of implementation of the first two revolutions, information technology, communication techniques and micro-electronics are the basic components of this revolution (Çeliktaş et al., 2015). Today, we are heading towards a new industrial revolution.

***Fourth Industrial Revolution*:** Which will introduce Cyber-Physical Systems-based manufacturing. This fourth stage of the industrial revolution has a very different approach from all other stages. The first industrial revolution was based on steam-powered manufacturing mechanisms followed by the second industrial revolution which brought with it the mass production with the utilization of electric power. Later, the digital revolution, the third industrial revolution, took place and the use of electronics was increased. However, the fourth stage is defined as the project of encouraging the existing industry towards computerization and of equipping it with high technology (Kagermann et al., 2015; Çeliktaş et al., 2015). This new revolution, referred to as Industry 4.0, has emerged with the machines starting to manage themselves and their production processes without the need for human labor. With Industry 4.0, production processes will acquire modular and flexible manufacturing capabilities which can make decisions on their own but which can also be integrated with other production areas. In this new era where technology is used at every stage of the production process, the machines, each driven by a different computer, will now be under the control of a host computer as a whole (haber.tobb.org.tr, 2016). In the direction of these developments, physical strength-based traditional factory models are being abandoned, and robot- and machine-based smart factories are becoming widespread (kobi-efor.com.tr, 2017).

Era of smart factories in industrial revolution: industry 4.0

The term Industry 4.0 was first used in Germany's Hannover Fair in 2011 with the aim of the German Government securing the near-future position of the manufacturing industry by equipping it with advanced technology. To this end, a working team that was brought together in 2012 prepared a final report in 2013 and made it into a research agenda. In this new approach referred to by developed countries as “polylemma of manufacturing;” a journey to a fictional perfection defined as individualization, virtualization, hybridization and self-optimization has begun (Brettel, et al., 2014). According to the main framework of the new industrial revolution, the primary purpose is to make sure that machines, computers, sensors and other integrated computer systems in a factory can exchange information with one another via internet during manufacturing and can manufacture by coordinating and optimizing themselves almost completely independently from human operators.

As a result of the advantages provided by the optimization, it is anticipated that the manufacturing period, the costs and the amount of energy needed for manufacturing will be reduced while the manufacturing quantity and quality will improve (Imtiaz and Jasperneite, 2013). In this new era referred to as Industry 4.0, computers that previously managed individual machines will now be able to manage factories. This period of time when computers manage factories is also referred to as

“*Era of Smart Factories*" or “*Era of Smart Manufacturing*”: (haber.tobb.org.tr, 2016). Creating a smart factory is only possible with "Cyber-Physical Systems" (CPS) and "Internet of Things (IoT)." CPS refers to the process in which physical machines become much smarter as a result of communication and coordination thanks to cyber technology while Io T refers to the process in which objects communicate with one another via internet and manage themselves (www.ebso.org.tr, 2016). Smart robots that will be used in smart factories in the new industry era will be able to recognize through sensor technology the materials moving on the assembly line and decide which process those materials should go through. This will make sure that each product is processed with zero errors in the same production line. At the next stage, connected machines which are in communication with one another will be able to monitor the quality of the product and spot errors in the production process more quickly. All this process is planned to be managed by interconnected cyber physical systems. Industry 4.0 revolution focuses on manufacturing and service innovation involving cyber physical systems in which modern information and communication technologies such as cloud computing will be integrated into systems in order to improve productivity, quality and flexibility in the manufacturing sector and will provide an advantage in the competitive environment by analyzing possible yield situations (Çeliktaş et al., 2015). Industry 4.0 can in fact be described as the digitalization of the industry.

To put it more precisely, what we call digital today is already used in the machines, products, materials, equipment and even in the vehicles which carry them and all these elements are connected to one another. An integrated communication can be implemented between all the value chain creation elements (human, machine, material, product, vehicle, equipment, etc.) in Industry 4.0 (alpustundag. blogspot.com.tr, 2017). From this point of view, Table 1 demonstrates the expected future developments and trends of the value chain creation factors in Industry 4.0.

Technological Factors Triggering Industry 4.0 and Their Contributions to the Production Process

Since the concept of Industry 4.0 first appeared in Germany, it has been widely known in Europe and is becoming more and more recognized every day on the global scale. Aiming to bring information technology and industry together, Industry 4.0 has a flexible manufacturing structure that can work in an integrated way with other manufacturing areas. Smart factories, Internet of Things, 3D printers, augmented reality, cloud computing system, system integration, simulation, autonomous robots, large data and its analysis, and cyber-physical systems are very important technological elements that play a role in triggering this revolution (www.ebso.org.tr, 2016). Enabling faster, more flexible and more efficient processes, these systems will become widespread in the era of Industry 4.0. In addition, these systems will make the manufacturing of goods of higher quality at lower costs possible which will result in a reduction in costs in manufacturing and an increase in productivity (tusiad.org.tr, 2016). In this context; Table 2 shows, by giving examples from the industry, the effects on the production process of some technological factors that have triggered industry 4.0.

Table 1. Trends and expected developments for value creation factors

Equipment	The implementation of greatly computerized machine instruments and robotswill define the manufacturing equipment which will have the capacity of flexibility to adjust itself to modifications in the other value creation factors such as robots collaborating with the workers to perform joint tasks (Kagermann et al., 2015).
Human	Full automation is putting the existing jobs in manufacturing at high risk of disappearing which will lead to a decrease in the number of workers in the industry (Frey and Osborne, 2013). The remainder of jobs in manufacturing industry will involve in more knowledge-based areas and tasks which are more short-term and more complicated to perform (Spath et al., 2013). The tasks assumed by the workers concentrate more on overseeing the automated equipment. This way, they are being incorporated into decentralized decision-making processes and constituting an integral part of end-to-end engineering activities (Stock and Seliger, 2016).
Organization	It is impossible to tackle the manufacturing system from a center instance as it becomes more and more complicated in terms of its organizational structure. It is, therefore, inevitable that after a certain point,decision making processes will be handled by decentralized instances which will independentlytake into account localized information regarding decision-making processes (Kletti, 2015).The workers or the artificial intelligence-based equipment will be in charge of making the decisions (Stock and Seliger, 2016).
Process	There will be an increase in the utilization of additive manufacturing technologies, also referred to as 3D printing, in value creation processes as these technologies have been cheaper, faster and more precise for the last years. This situation will make it possible for the designing of stronger, lighter and more complicated geometries, and for the implementation of additive manufacturing to manufacture a larger number of products (Hagel III et al., 2015).
Product	Specific demands of customers will be taken into account for the manufacturing of a product in batch size one which will enable the customer to be a part of the value chain almost at the beginning of the mass customization of the product. Within the context of new business models, the product will also bring with it new services which provide functionality and access for the customer instead of the customer just being the owner of the product (Hagel III et al., 2015).

Source: Stock and Seliger, 2016.

Table 2. Some Technological Factors Triggering Industry 4.0 and Their Contributions to the Production Process

Technological Feature	Example from Industry	Effect on Production Process
Big Data and Analysis	Infineon Technologies	Reducing product failures and increasing productionquality in the production process
Smart Robots	Puppet and A38	Robots that can adjust their behavior to be ready for the next product assembly on the production line can interact with oneanother and with people and recognize workpieces
Simulation	Siemens	80% reduction in preparation time needed for machining process thanks to a virtual machine simulating the machining of workpieces
Vertical and Horizontal System Integration	Dassault Systèmes	The platform that provides a cloud-based service on design and manufacturing can efficiently manage complex operations which multiple business partners share product and production data
Internet of Things – IoT	Bosch Rexroth	The process in which products are marked by radio frequency codes and workstations “know” which manufacturing steps need to be carried out for each product and act accordingly
Cyber Security	Atos	With Bull, Atos offers solutions not only to manage risks and uncertainties, but also to use security as an important leverage in embracing digital transformation (siemens.e-dergi.com, 2017).
Additive Manufacturing - 3D Print	Aviation Companies	Making use of additive manufacturing techniques for making new designs to reduce the expenditures for raw materials and reduce the weight of the aircrafts
Augmented Reality	Virtual Training at Siemens	Operators can interact with other machines via the cyber model, modify parameters, and access operational information and maintenance instructions
Cloud Computing System	Google Drive	This is a file storage and synchronization service created and managed by Google. This service allows users to store documents in the cloud, share files, and organize documents with people they collaborate with (wikipedia.org, 2017).

Source: tusiad.org.tr, 2017.

Industry 4.0 Design Principles

Industry 4.0 has determined six design principles by which automation or digitization operations are carried out by manufacturers or producers for production purposes (Herčko et al., 2015).

- Interoperability: A critical element of Industry 4.0 for enterprises, interoperability is a concept which refers to CPS and people that are connected through the Internet of Things (IoT) and Internet of Services (IoS). The success of interoperability depends on integration and interoperation of these network technologies.
- Virtualization: Refers to the generation of a virtual - rather than actual - version of operating systems, computer network resources etc. Physical processes can be monitored via CPS. Sensor data are integrated into virtual enterprise and simulation models, which make it possible to transform the physical world into a virtual environment in which physical processes can be simulated (Mıčıeta et al., 2014).
- Decentralization: The increasing demand for products entails more complex operations requiring series of decisions that have to be made. Through decentralization, devices are incorporated into decision-making processes and allowed to make decisions on their own, which facilitates the operations of the central control system of an organization.
- Real-time capacities: Control systems are an indispensable part of real time data collection and analysis. They can easily adapt and respond to failures, malfunctions or production shifts in real time based on collected data.
- Service-orientation: Connected to one another via the IoS, services, companies, CPS and people can be offered or recommended to third parties, which could be internal or external. For instance, Web is a means of accessing services.
- Modularity and reconfigure ability: Having the capacity to adapt to changing requirements to expand or to transform modules, modular systems are easily editable for the planning and optimization of seasonal fluctuations or shifts in production processes. An example of modularity modules is plug & play. The system should also be able to automatically configure changes and transformations (Haluška, 2013; Gregor and Haluška, 2013).

Opportunities of Technological Transformation of Manufacturing for Businesses and the Economy of the Country by the Application of Industry 4.0

With the introduction of Industry 4.0, new opportunities such as flexible manufacturing, smart supply chain, custom manufacturing, innovative business models and a new way of work are expected to be offered to businesses. Some examples for these opportunities will be presented and they will be evaluated briefly.

Flexible manufacturing: In a factory where the system of Internet of Things is actively used, the production process will be managed by machines and robots which can automatically stop the process by making the necessary interventions in case of a problem during manufacturing (www.ebso.org.tr, 2016). Robots will be smarter in the future and able to adapt to and communicate and interact with their surroundings more easily. Robots taking over the production process will bring about the need for human labor in order to evaluate the resulting data in an analytical manner and to intervene in the system in real time (www.atayatirim.com.tr, 2016).

Smart supply chain:Thanks to Industry 4.0, not only will the production process become practical, but supply chain management will also become smarter. Sensors and smart tags placed on products will enable the products to self-manage throughout the supply chain. One of the factors that plays an important role in the global competition is reaction and adaptation to changes. Industry 4.0 will provide transparency and therefore capability of both flexible and fast reaction. For example, if a supplier is having trouble with the product shipment, another supplier will automatically step in and the production will continue without a problem and loss of time. The production processes will be plainer and designed in such a way that their dependence on/independence of specific geographical environments will be optimized (www.mobilyadergisi.com.tr, 2017).

***Custom manufacturing*:** Industry 4.0 will provide the transition from mass production to custom manufacturing based on individual customer needs. Thanks to the manufacturing technique of Industry 4.0, a special customer product will be designed, prepared and delivered in a short span of time. In addition, these requests will be materialized by the participation of people who are independent of and miles away from one another. While the manufacturing and its various stages are clear cut in the old system, thanks to the information technologies, sudden reactions expected of manufacturing will be possible to be apparent in the future. For example, if a product needs to be painted in blue or red, a machine will decide according to the details of the order as it will be in a position to make that decision. Long-running programs will no longer be needed in the machines due to flexibility and integrative structures. With this method, both specific demands of customers will be responded and machine efficiency will increase with the elimination of the small-to-large volume difference (www.mobilyadergisi.com.tr, 2017).

Innovative business models: Industry 4.0 can also lead to the emergence of new jobs in businesses. As this new industrial revolution keeps conquering our lives, new interdisciplinary roles combining software, information technology and traditional engineering competencies with communication are expected to emerge. In addition, people who can develop analytical platforms and algorithms, and people who are competent in statistics, data engineering, advanced programming, uncertainty modeling, loop recognition and learning, and data management and visualization, in short, those who are competent in "advanced analytical" issues will be able to distinguish themselves (www.atayatirim.com.tr, 2016).

A new way of work and its time: New smart assistant systems will provide new possibilities for workers. As robots speed up the production processes, the working time of the workers will be more flexible and independent of a certain location. According to the demographic developments, the number of elderly people in western societies is increasing, and it is thought that their working life can be prolonged with this new way of work (www.mobilyadergisi.com.tr, 2017). In addition to the advantages provided by Industry 4.0 for businesses, it is also expected to make a number of contributions to the country's economy such as productivity, growth, investment and employment. These contributions will be evaluated briefly with some examples from the world and Turkey.

Productivity: According to the report titled "Industry 4.0 as a Necessity for Turkey's Global Competitiveness" prepared in cooperation between TUSIAD and Boston Consulting Group (BCG), the productivity of the manufacturing sectors in Turkey is expected to be worth as much as 50 billion TL in the case of successful implementation of Industry 4.0. Considering the total cost of production, this analysis is based on the expectation that the increase in productivity will be between 4 and 7%. Only conversion costs (manufacturing cost excluding material costs) taken into account, the productivity increase is expected to be between 5 and 15% (www.tusiad.org, 2016). A significant improvement is expected in the global competitive power of Germany which is one of the leading economies of this transformation. A detailed study by BCG in 2015 shows that the productivity gains generated by the German manufacturing sector, which has started to implement Industry 4.0, will be between 90 and 150 billion euros within the next 10 years, with a 5-8% reduction in total production cost (www.otomasyondergisi.com, 2017). Manufacturing productivity can be achieved through more efficient use of resources. Industry 4.0 approach incorporates the basic tools to achieve this. The ability of the systems to operate with much less energy will result in the elimination of waste of resources which will also have a positive effect on the environment (alpustundag.blogspot.com, 2017).

Growth**:** Transition to industry 4.0 requires major investments, radical transformations and technological advances. High level of automation of the industrial processes and investments required to build smart factories bring with them the promise of significant growth (www.endustri40.com, 2017) because investments in new trends in the industry and in new technologies are made in order to meet the most basic customer expectations. The return of investments in these new technologies also means economic and industrial growth for both businesses and countries. According to the report prepared in cooperation between TUSIAD and BCG indicates that integration to the global value chains and the competitive advantage which will be gained by the economy around Industry 4.0 are expected to trigger an increase in industrial production of up to 3% per year in Turkey. This growth means an increase of over 1% in Turkey's GDP and an additional growth of about 150-200 billion TL (www.tusiad.org, 2016). With this new technology, an increase of 30 billion Euros is estimated in the annual turnover of Germany, the pioneer of Industry 4.0, and 100 billion Euros throughout Europe (www.endustri40.com, 2017).

Investment**:** According to the report prepared in cooperation between TUSIAD and BCG it is estimated that approximately 10-15 billion TL (about 1-1.5% of the producers 'revenues) should be invested per annum in the next 10 years - based on today's prices and economic size – in order to integrate Industry 4.0 technologies into the manufacturing process (www.tusiad .org, 2016). The results of the research conducted by the PwC research company with 235 companies in Germany reveal that the enterprises plan to allocate 3.3% of their annual turnover to Industry 4.0-focused projects over the next 5 years. The state support these projects will receive is expected to contribute to the acceleration of the process. It is estimated that the annual amount of Industry 4.0 investments in Europe will reach 140 billion Euros. The German government is also investing heavily in the industry for Industry 4.0, which is shaped by the contribution of non-profit organizations in the United States and by the government support in Finland and China. The German government's 40 billion euros worth annual promise of investment for Industry 4.0 projects until 2020 creates an attractive innovation environment for private sector enterprises (www.endustri40.com, 2017).

Employment**:** The two biggest concerns about Industry 4.0 are safety andjob loss as a result of the widespread use of robotic systems. However, all we have to do is look at the period of the Third Industrial Revolution in order to see that these concerns are not realistic. During this revolution, automation increased especially in the automotive sector while unemployment did not. On the contrary, economic growth with the Third Industrial Revolution led to the birth of new and innovative business areas, the emergence of new professions (such as the maintenance and repair of automation robots and machines) and increased job opportunities. Therefore, Industry 4.0 is also expected to bring with it new opportunities. It is envisaged that Industry 4.0 investments will provide 6% employment growth in the short term, while in the long term, it will considerably increase the demand for qualified workforce especially in Information Technologies and mechatronics areas (www.endustri40.com, 2017). Assuming that the growth targets will also be reached, it is predicted that the workforce requirement in the total industry will increase, and more importantly, a much more qualified workforce structure with high education and income level will come into existence. In this context, even though it is likely that the workforce with low level of competence in employment will decrease in the next decade, it is expected that there will be an absolute increase in employment in total with an increase in the industrial production. It is also considered that high-quality workforce structure will enable the development of the infrastructure of the income pyramid and of the "know-how" of Turkey (www.tusiad.org, 2016).

Industry 4.0 Applications from Turkey and the World

The foundations of Industry 4.0, which first became widespread in Europe, were laid in Germany. Later, it soon found itself an area of activity thanks to industrialized countries such as the USA and Japan. The Global Competitiveness Index Report (GCIR) published by the World Economic Forum (WEF) in 2016 measured the relative readiness of 138countries for adaptation to Industry 4.0depending on their overall impact rankings. According to GCIR, the lower the overall impact score of a country, the better that country is in terms of its readiness to the adaptation process. According to the rankings of 138 different countries, Switzerland ranks first, Singapore second, the United States third, Netherlands fourth and Germany fifth. Although the foundations of Industry 4.0 were laid in Germany, it ranks 5th in the list preceded by Netherlands (WEF, 2017).Germany needs to improve its current Internet infrastructure, allocate more funds to R&D and increase the number of qualified personnel in order to be successful in the new industrial revolution (Thobena et al., 2014).

According to the report prepared in cooperation between TUSIAD and BCG states that Turkey, which is among the developing countries, is in a very competitive position in the global value chain thanks to its geographical location providing logistic advantage and thanks to low cost labor utilization. In the BCG Global Manufacturing Cost Index, which is based on manufacturing fees, productivity, energy costs and exchange rates, Turkey manufactures at an average unit cost of 98 while the USA at an average unit cost of 100 and Germany at an average unit cost of 121.In other words, direct manufacturing costs in Turkey are 23% and 2% below those in Germany and the USA (www.moment-expo.com, 2017). Despite this cost advantage, Turkey ranks 55th in the Global Competitiveness Index Report (WEF, 2017). According to the report prepared in cooperation between TUSIAD and BCG, some of the obstacles in front of Turkey's adaptation to Industry 4.0 are; slowing down of investments in capital-intensive systems as a result of structurally cheap labor costs, delaying of the widespread use of new manufacturing technologies due to limited qualified workforce and ecosystems, accelerating employee turnover with the shift of workforce from industry to service sector and delaying of the formation of an experienced workforce (www.emo.org.tr, 2017). Placing special emphasis on training strategies for the formation of a qualified workforce that will be active in manufacturing can be considered a feasible strategy to overcome these obstacles.

Aside from political issues, all global platforms and the business world have been concerned with the issues of climate change, sustainability and the scope of the Fourth Industrial Revolution over the past three years. Having first emerged in Europe, especially in Germany, and later in the United States and other developed English-speaking countries, the Fourth Industrial Revolution is at the agenda of the whole world and Turkey (Fırat and Fırat, 2017).Both large scale companies and SMEs in many different sectors in Turkey and in the world wish to take advantage of productivity growth in competition, cost and production processes and therefore seem to adapt to Industry 4.0 applications. A literature review was conducted to determine the companies that support Industry 4.0. Their activity areas/sectors and origins are given in Table 3. Several Industry 4.0 applications of these companies are examined in detail in the following sections.

Table 3 shows some companies that support Industry 4.0 together with their activity areas/sectors and origins.

MindSphere – Siemens Cloud for Industry

Siemens derives its power in the global market from automation technologies. Developing autonomous manufacturing systems with self-regulation and follow-up capability through which the virtual and the real world are interconnected, Siemens predicts that each component in the production flow and data generated by these processes are analyzed using big data. The Integrated Software Engineering solution referred to as the Digital Enterprise Software Suite that manages the product life cycle is an example of this strategy. Siemens has developed the Industrial Cloud Platform Mind Sphere, which houses low-cost data using the Digital Enterprise Software, and it is available for companies manufacturing with Industry 4.0 technologies. With Mind Sphere, Siemens aims to provide digital data and innovative solutions to the industry, release faster, better and more efficient products to the market and merge physical products and product facilities. Siemens provides a reliable cloud technology with a SAP's HANA-based open data infrastructure which enables the creation of digital services for industrial enterprises. Customers and developers can use the cloud applications to develop, expand and operate on this open platform. Original Equipment Manufacturers (OEMs) and application developers have access to open interfaces through which they can use their own service and analyses on this open platform such as online monitoring of globally distributed compressors and pumps or access to and supervision of industrial robots and equipment etc. With MindSphere, Siemens also allows customers to create digital models using real data in the manufacturing process in their own facilities, which gives them the opportunity to run simulations and optimize their business processes, allowing them to synchronize their models and machines. In the future, users will also be able to operate this platform to develop their own web services for such digital services as preventive maintenance, energy data management or resource optimization (www.endustri40.com, 2017).

Bosch Smart Home Systems

As one of the world's leading suppliers of products and services, Bosch has played a pioneering role all over the world, especially in Germany, with regard to Industry 4.0. Having successfully completed dozens of projects in more than 250 facilities around the world and implementing Industry 4.0, Bosch advocates networked technologies and offers its customers such solutions as sensors, drives, and even robot assistants. Using its own cloud Bosch IoT Cloud in its Web-based services, Bosch has now connected more than five million devices and machines to the network. One of Bosch's industry-leading 4.0 products is Smart Home Systems, which can be remotely controlled using a single application on a smart phone. The Bosch Smart Home System enables users to connect their home’s heating and lighting systems and smoke alarms and devices via a single platform and run them using a smart phone or tablet. There is a controller in the center of the system. This central control unit connects the components mentioned above to each other and to the Internet. The system also has a small radiator thermostat and a sensor-based window contact. All data generated by the smart home is stored in the smart home controller, which means that customers have control over their own data. These data are encrypted before transferred to the IoT Cloud. In future versions of the product, the system will send a message to the smartphone when a window or door is opened, which will increase comfort and safety without the need for a separate alarm system. Another solution that runs in the Bosch IoT Cloud has been designed for heating service technicians. In the event of a breakdown, technicians can remotely access Bosch heating systems to troubleshoot problems. In this way, they can bring the necessary replacement parts that are needed for the repair, which reduces the number of visits to one. Customers also benefit from low service charges. Smart home solutions are projected to have a global market potential of 10 billion euros next year (www.iot.gen.tr, 2017).

GE Predix Cloud Platform

GE is one of the companies that pioneer the spread of the Fourth Industrial Revolution in the world and take remarkable steps in digitalization. It advocates that the digitalization of the industry will provide great contributions to developing economies. The first cloud-based industrial operation system for industrial internet, Predix was introduced to software developers by GE. Predix was developed for industrial machines. This platform provides producers with the opportunity to collect all kinds of data of production vehicles, store them in cloud computers, analyze them and develop innovative solutions. Furthermore, this platform provides support for the digitalization of customers and encourages software developers to develop applications in different industries, from medical devices such as computerized tomography or MR to aircraft engines.

Making factories smarter and lowering costs, GE's Industrial Cloud platform Predix makes the advantages of the new age available to the general public. With Predix, many companies collect data from airplanes, trains, power plants and other fields of technology, and all data accumulates in the cloud waiting to be analyzed. For example, the Schindler Group, one of the world's largest elevator manufacturers, used GE's Predix platform to lower the electricity use of elevators and escalators. The Schindler Group can transform elevators and escalators into self-optimizing systems by installing small computers in all of them in order to enable them to use electricity more efficiently. In fact, it is possible for the Schindler Group to use various applications at the same time to implement this technology because Predix users can now use 100 applications on a single machine (geturkiyeblog.com, 2017).

Festo ExoHand

Festo, one of the main companies that apply Industry 4.0, has turned its steps towards the manufacture of products in many sectors in accordance with the Fourth Industrial Revolution. Carrying on its operations with a sustainable innovation management approach, Festo has had many developments especially in the field of robot technology by making machines that can move identically with people and other living things.
Developed by Festo, ExoHand is an active manual orthosis with sensitive fingers and an outer skirt that can be worn like a glove. Fingers can be actively moved and their strength can be reinforced. The hand movements of the operator are recorded in real time and sent to the robot arm. The aim of the project is to improve the strength and stamina of the human hand. ExoHand can be used for power amplification in monotonous and overexerting operational tasks in industrial assembly settings. For example, in hazardous environments, the operator can benefit from power feedback to understand what the robot arm is holding and handle the situation without having to enter the dangerous area or touching hazardous chemicals/materials. Thanks to the high power output of the pneumatic elements, ExoHand can also be used in service robot industry. Stroke victims may benefit from Festo's ExoHand during rehabilitation process.

Festo's ExoHand will be used as an active manual orthosis in the field of rehabilitation in the future. The active manual orthosis can help bring back the severed connection between the brain and the hand of patients with the onset symptoms of paralysis whohad a cerebral hemorrhage. A brain-to-computer interface recognizes electroencephalographic signals (EEG) from the brain and understands that the patient wants to open or close his/her hand. The movements are performed by ExoHand using a brain-to-computer interface. This creates an educational effect and the patient can learn over time to move his/her hands again without any technical assistance (http://www.otomasyondergisi.com, 2017).

Mitsubishi Electric - e-F@ctory

E-factory can combine the best automation components in its class with a single compatible system, providing benefits such as lowering costs, and increasing productivity and quality. The aim is to guarantee a regular flow of information from the first stage to the last stage of production. MESs (manufacturing execution systems) must provide real-time information on situation assessments necessary for the optimization of production output. Such systems are used to meet end-user expectations in production, which are an increase in production, quality improvement, flexibility in production, production planning, simple information exchange between order and production data, and automation instead of manual data entry.

The Mitsubishi Electric e-factory solution comes into play to meet these expectations and ensures that production and management departments of a factory communicate with each other from a single point without interfering with each other.The e-factory has been used by Mitsubishi Electric for a long time for effective automation in its own factories, covering everything from planning to installation, operation and maintenance. Thus, while achieving high productivity, it also helps end-users to realize machine benefits and quality (www.otomasyondergisi.com, 2017). In short, the e-F@ctory concept, which is a response of Mitsubishi Electric to Industry 4.0, is an evolutionary step that can provide very significant cost savings while increasing speed, quality and productivity. This section addresses a number of examples of Industry 4.0 applications from leading companies such as Siemens, Bosch, General Electric, Festo, and Mitsubishi, and briefly mentions Industry 4.0 applications in pilot sectors in Turkey. Industry 4.0 applications are being implemented in Turkey in four pilot sectors; white appliances, machine systems, automotive and chemicals. Table 4 presents the examples of Industry 4.0 applications according to Industry 4.0 indicators such as integrated, automated and excellent production flow, virtual product design, flexible manufacturing, smart and optimized logistics and learning processes.

TUSIAD and BCG collaborated and conducted in-depth interviews with a total of 25 Turkish manufacturing companies/groups operating in six different sectors in order to demonstrate the potential impact of Industry 4.0 on Turkey. The results indicate that the potential benefits of Turkey's Industry 4.0 transformation in the pilot sectors are productivity and cost increase. The report states that it is possible to increase productivity 10-15% *in the automotive sector*, 9-14% *in the white appliances sector*, 10-16% *in the textile sector*, 8-12% *in the chemical sector*, 9-12% *in the food and beverage sector* and 9-12% *in the machine sector*. According to the same report, cost increase is expected to be 5-7% in the *automotive sector*, 6-9% *in the white appliances sector*, 4-9% *in the textile sector*, 3-4% *in the chemical sector*, 5-9% *in the food and beverage sector*, and 4-8% *in the machine sector* in the form of productivity increase (tusiad.org.tr, 2016). A detailed analysis of the selected sectors shows that Industry 4.0 transformation has provided significant value creation opportunities. The graph in Figure 2 presents this situation on the basis of the sectors. This assessment covering different sectors shows that the opportunities offered by Industry 4.0 are not only in theory but also in practice and of critical importance to Turkey.

RESULTS

While the First Industrial Revolution was based on the mechanism of production using water and steam power, it was followed by the Second Industrial Revolution with the introduction of electric power-based mass production. The Third Industrial Revolution was a digital revolution which increased the use of electronics.

Industry 4.0 comes into the picture as an endeavor that optimally responds to these challenges. The main objective of the Industry 4.0 approach, which means the Fourth Industrial Revolution, is to bring about a flexible production process, and manufacturing with minimum cost and maximum productivity in smart factories. The aim of Industry 4.0 is to enable the machines, computers and objects in factories to exchange information during manufacturing with oneanother through internet entirely independently of human operators. With this new approach, factories will be built on a completely technological infrastructure. Human workforce will be replaced by smart robots and machines in smart factories during the production process.

Table 3. Companies that Support Industry 4.0

Company Profile	Industry 4.0 Activity Area/Sector	Origin
Bossard – Ergon	Fasteners, Engineering, Logistics Sector	Switzerland
Mitsubishi Electric Factory Automation	Electric and Automation Systems	Singapore
Bosch Rexroth	Drive and Control Technologies	United States
General Electric	Electronics and Banking Sector	United States
İntel	Semiconductors Industry	United States
Microsoft	Software industry & Computer hardware & Consumer electronics	United States
FESTO	Automation Technology	Netherlands
Scheer	Software and Consultancy Sector	Germany
BMV	Automotive Industry	Germany
AUDI	Automotive Sector	Germany
Mercedes	Automotive Sector	Germany
ARBURG	Automotive and Plastics Sector	Germany
Siemens	Industry Sector	Germany
Bosch	Electronics and Engineering Sector	Germany
SAP Software Company	Software Company	Germany
Beckhoff	Automation Technology Company	Germany
FESTO	Industrial Automation Sector	Germany
Atos	IT Service and IT Consulting	Germany
IKEA	Furniture Sector	Sweden
Ericsson	Networking and Telecommunications Equipment Manufacturer	Sweden
WITTENSTEIN	Machine Tools and Packaging Industries	Sweden
Mitsubishi Electric	Electric and Electronic Sector	Japan
Cisco Systems Hong Kong Ltd.	IT and Networking	Hong Kong SAR
Ponsse	Forest Machine İndustry Sector	Finland
Ekornes ASA	Furniture Sector	Norway
IBM Denmark Ltd.	İnformation Technology (IT) Products and Services.	Denmark
Kaeser Compressors NZ Limited	Industrial Air Compressors	New Zealand
Quaser Machine Tools	Machine Tool İndustry	Taiwan, China
Ifourzero Technologies Inc.	Industrial Machinery Sector	Canada
SAMSUNG	Mobile & TV & White goods	Turkey
Boğaziçi Software	Software Sector	Turkey
Vestel	Electronics, White Goods and Information Technology	Turkey
Arçelik Inc.	White Appliances and Technology	Turkey
Borusan	Steel & Distributorship & Energy & Logistics	Turkey
Havelsan	Defence & Software Industry	Turkey
Panasonic Eco Solutions	Electronic Goods & Switch Socket Sector	Turkey
Şişecam	Glass Manufacturing	Turkey
Turkcell	Telecommunications Industry	Turkey
Eczacıbaşı	Pharmaceutical Sector	Turkey
CMS Wheel and Machine	Wheel and Automotive Subsidiary Industry Sector	Turkey
Başöz Energy	Energy Sector	Turkey
Artesis	Software and Technology Company	Turkey
Ermaksan	Machinery and Motor Sector	Turkey
Çalık Holding	Energy, Telecom, Textile, Construction, Finance and Mining Sectors	Turkey
Ektam	Bottling Facilities Manufacturing Sector	Turkey
Frekans Mach.	Machinery and Automation Sector	Turkey
MCS	Software and Automation Sector	Turkey
Volkan Engr.	Machinery Manufacturing and Subsidiary Industry Sector	Turkey
SGS Automation and Drive	Iron-Steel and Casting, Chemical, Aerospace, Automotive and Paper Sectors	Turkey
Lodos Technical	Industrial Machinery and Automation Sector	Turkey
Zorlu Holding	Textile, Energy, White Appliances, Electronics and Finance Sectors	Turkey

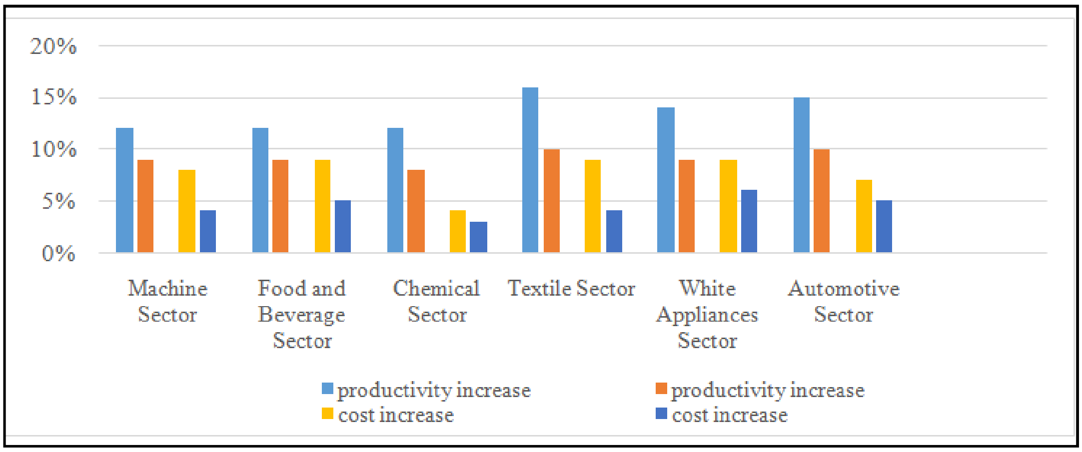
Today, while demand for customized products is increasing, productivity, speed and flexibility of industrial companies have to be continuously improved due to global competition. All these factors require production processes which are as flexible as possible.

This way, human errors will be minimized and more goods of higher-quality will be manufactured in less time. The production line at the factory will also become smarter in this process. For example, when a customer orders a product, the order will automatically reach the factory which will manufacture as many as the customer demands.

Table 4. Industry 4.0 Applications in Pilot Sectors in Turkey

Industry 4.0 Indicators	Sector	Examples
Integrated, Automated and Perfect Production Flow	White Appliances	Integrated quality management Products are monitored during the manufacturing process and waste is reduced based on the failure data of the tests conducted after preliminary production, and processing is improved
	Machine Systems	Integrated design data In the manufacturing process, vertical data integration is used to optimize operations from design to the end of the production line
	White Appliances	Horizontal data integration Integrated manufacturing process is more achieved by allowing suppliers to see some ERP data
Virtual Product Design	Automotive	Virtual factory and product design A joint solution integrating factory and product design is offered in order to optimize manufacturing with factory simulations based on actual manufacturing needs
Flexible Manufacturing	White Appliances	Flexible manufacturing robots A production line communicating with RFID-based smart products and adapting the tools and manufacturing tasks according to the range of products has been put into practice
Smart and Optimized Logistics	Automotive	Laser-guided auto-guided vehicle (AGV) Laser-guided logistics systems are used where the server computer controls the inventory and production schedule and deliveries and directs AGVs
Learning Processes	Chemicals	Self-optimizing process flow Quality of the final product line is optimized by recognizing problems in the basic material mix by using IT algorithm

Source: tusiad.org.tr, 2016.



Source: http://www.tusiad.org.tr, 2016.

Figure 2. Productivity and Cost Increase in Pilot Sectors of Turkey with Industry 4.0 Transformation

In the meantime, the supply chain and logistics of these products will proceed separately from these processes and this process will end with the delivery of the products to the customer. Thus, the Fourth Industrial Revolution will bring about a problem-free manufacturing system which operates extremely smartly and smoothly. Nowadays, when the world quickly adapts its information technologies to different fields and enters a new industrial revolution, it is a matter of extreme importance that Turkey should catch up with this revolution. Having lagged behind in the previous industrial revolutions, Turkey can reduce the very same risk this time by embracing the concept of new industry from the beginning. Turkey should start making better use of its existing industrial advantages and improve them step by step. Turkey needs to pay attention to all scientific and technological advances, and transformations in the product and production structure which affect the Industry 4.0 stage and develop strategies accordingly in order to adapt to this transformation. R&D expenses are considered to be an important indicator which manifests the difference in terms of the level of development between countries. Referred to as a middle income trap by economists, the position of Turkey does not allow it to reach the category of developed countries due to the fact that it adopts a mode of production that is far from the culture of R&D and innovation, and follows traditional business models.

Turkey should go through a structural and cultural transformation in the fields of R&D and innovation in order to keep up with the world-wide transformation and to break away from this middle income trap. To achieve this, it is of prime importance that Turkey improves its R&D capability and encourages the industry to cooperate. In addition, encouraging scientific institutions and universities in Turkey to contribute to these studies can also have important advantages. The adoption of Industry 4.0 in enterprises is expected to provide a number of advantages and opportunities such as flexible manufacturing, smart supply chain, custom manufacturing, innovative business models, new working styles and hours. The Industry 4.0 approach is recognized by leading global companies such as Siemens, Bosch, General Electric, Festo and Mitsubishi as a productive business model that allows for the collection, observation and analysis of each data in the manufacturing environment. For this approach, Internet of Things, internet services, cyber-physical systems and systems of data exchange between customers and suppliers are indispensable parts of the whole process. It can be stated that enterprises that make use of these Industry 4-based systems aim to achieve more cost-effective production in larger quantities with higher quality and reliability at higher speeds with at least twice the efficiency, and minimum energy use, less heat generation, and less resource and memory use.

From the public perspective, it is necessary to support the advance of technological infrastructure in line with Industry 4.0 all over the country. Moreover, preparing the necessary investment and incentive environment and ensuring the formation of a much-needed qualified workforce by implementing long-term education policies can be regarded as other important priorities.

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