INDUSTRY 5.0 AND A CRITIQUE OF INDUSTRY 4.0

Abstract: Industry 4.0 is at the door. It is being discussed by scholars and practitioners in conferences, symposiums, and seminars. Fourth industrial revolution comes with a lot of promises for the future of effective and efficient manufacturing. It is interesting that Industry 5.0 is already being discussed in forums and blogs. In discussions related to Industry 5.0, Industry 4.0 is being criticized with not being able to provide solutions for all foreseeable future needs. While the focus of Industry 4.0 is mass production, Industry 5.0 focuses on sustainability. In this paper, we provide a critique of Industry 4.0 and briefly present the arguments for Industry 5.0. Furthermore, we emphasize that regardless of its version, the next industrial revolution should be fueled by both the information technology and the concerns for environmental sustainability.

Keywords: Industry 4.0, Industry 5.0, Sustainability, Sustainable Manufacturing, Human Robot Coordination, Zero Waste, Industrial Upcycling

ENDÜSTRİ 5.0 VE ENDÜSTİ 4.0 ELEŞTİRİSİ

Özet: Endüstri 4.0 devrimi hemen önümüzdedir. Endüstri 4.0, konferanslarda, sempozyumlarda ve seminerlerde bilim adamları ve profesyoneller tarafından tartışılmaya başlamıştır. Dördüncü endüstri devrimi etkin ve verimli üretimin geleceği adına bir çok vaat ile birlikte gelmiştir. Çeşitli internet forumlarında ve bloglarda daha şimdiden Endüstri 5.0'ın tartışılmaya başlanması oldukça ilginçtir. Bu tartışmalarda, dördüncü endüstriyel devrimin şimdiki ve yakın gelecekteki ihtiyaçları karşılamada yetersiz olduğu vurgulanmaktadır. Endüstri 4.0'ın odağı seri üretimdeki artış iken, Endüstri 5.0'ın temel odak noktası sürdürülebilirliktir. Bu çalışmada, Endüstri 4.0 üzerine bir eleştiri getirmekle beraber Endüstri 5.0 için yapılan tartışmaları da sunmaktayız. Bunlarla beraber, sürümü ne olursa olsun bir sonraki endüstri devriminin özünde hem bilişim teknolojisinin hem de ekolojik sürdürülebilirliğin olması gerektiğini önemle vurgulamaktayız.

Anahtar Kelimeler: Endüstri 4.0, Endüstri 5.0, Sürdürülebilirlik, Sürdürülebilir Üretim, İnsan Robot Koordinasyonu, Sıfır Atık, Endüstriyel Geri Dönüşüm

INTRODUCTION

Various advancements in technology help us to achieve a significant increase in industrial output. This significant increase in industrial output create a chain reaction in industries and businesses. New products in large quantities become available. Supply and demand relations in many products and services change. New businesses are born. Existing businesses adapt. New industries are born and some become obsolete. Changes in inter- and intra-industrial relations are observed. Science and technology research receive funding for further research. All these changes affect the society in many ways. Therefore, we call this an industrial revolution.

There were three industrial revolutions in history. According to many, we are at the dawn of a new industrial revolution. This fourth revolution is called "Industry 4.0". The concept was recently introduced in 2011. "Smart Manufacturing" or "Smart Factories" are at the core of Industry 4.0. Since the introduction, there were many talks, discussions, conferences, seminars, and scientific research into the concept. However, while there is a remarkable support for Industry 4.0, there is also some criticism from various experts and scholars. One of the basic critique related to Industry 4.0 is that it is not a revolution but the same old IT-supported manufacturing. Furthermore, we have yet to see the changes previously observed in earlier industrial revolutions. So far, there is much talk but less change.

Even though it has been only a few years since the introduction of Industry 4.0, some intellectuals (such as Rada, 2015; Sachsenmeier, 2016; Østergaard, 2016; Gotfredsen, 2016; Rendall, 2017) started a discussion for Industry 5.0. Industry 4.0 is conceptualized and defined by a panel of experts and scholars with support from German Government. Therefore, Industry 4.0 is actually a predefined concept. The problem with a predefined concept is its difficulty in changing the definition. Therefore,

when experts have ideas related to an industrial revolution and these are outside its currently defined scope, it is natural that some come up with a new definition and a new version.

In this paper, we overview the industrial revolutions in the second section. Next, we briefly discuss Industry 4.0. In the fourth section, a detailed critique of Industry 4.0 is presented. We devote a special section for the discussions related to Industry 5.0. Finally, we conclude the paper with our arguments for what the next industrial revolution -regardless of its name and version- should include.

INDUSTRIAL REVOLUTIONS

According to Oxford dictionary, industry is the "economic activity concerned with the processing of raw materials and manufacture of goods in factories". The origin of the word goes to 15th century. However, the first industrial revolution started towards the end of 18th century. Naturally, all industrial revolutions are fueled by technological advances in manufacturing processes. Figure 1 depicts the industrial revolutions on a time line. Note the shortening of periods between each industrial revolution. There are 100 years between the revolutions up the third revolution. However, there is only 40 years between the third and the so-called fourth industrial revolution.

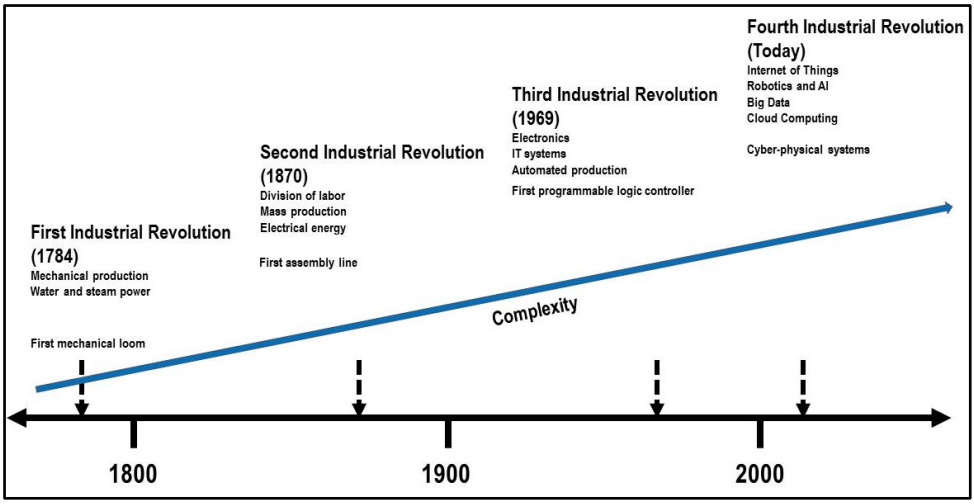

Figure 1. From Industry 1.0 to Industry 4.0.

Industry 1.0: At the end of 17th century, we started to observe manufacturing facilities equipped with water or steam powered mechanical manufacturing devices. We observed a significant boost in productivity with the help of industrial machines and new power technologies.

Industry 2.0: Second industrial revolution started in 1870 with the introduction of a division of labor and mass production. Electrical energy became the main power source during this industrial revolution. Towards the end of 18th century, we started to put more science into manufacturing and management of industries. In addition to technical advances in manufacturing and mass production, we also observed advances in management. During these times, classical management theory was born. In 1909, Frederick Winslow Taylor published "The Principles of Scientific Management". Henri Fayol published the "14 Principles of Management" in his book titled as "Administration Industrielle et Générale" based on his work and experiences as a mining company director.

Industry 3.0: Third industrial revolution started in 1969 with the introduction of electronics and information technology (IT) systems use in manufacturing. While the physical power is still electrical, the conceptual power is computing in the industry 3.0. The computing power enabled by electronics and IT was the key for this industrial revolution.

Industry 4.0: According to many industrialists, experts, and scholars, we are in the beginning of the fourth industrial revolution. As in previous industrial revolutions, various technological developments fuel the fourth revolution. Industry 4.0 is discussed in detail in a separate section.

Industry 5.0: The next industrial revolution is already being discussed in various forums and blogs. It is actually quite interesting to see that various futurists are talking about the next revolution while we are still discussing the beginning of an industrial revolution. Actually, this may be the result of the shortcomings of Industry 4.0. We devote a separate section related to industry 5.0.

According to World Robotics 2016 Report, in the beginning of 2016, the total worldwide stock of operational industrial robots is about 1.6 million units. In addition, between 2016 and 2019, an annual growth of more than 13% is estimated in industrial robot installations all around the world. In the next few years, a double digit growth is expected. According to the report (International Federation of Robotics, 2016), this high growth is the result of various developments including the following:

Table 1. Reasons for High Growth in Industrial Robot Installations

Industry 4.0, linking the real-life factory with virtual reality, will play an increasingly important role in global manufacturing.
Human-robot collaboration will have a breakthrough in this period.
Compact and easy-to-use collaborative robots will drive the market in the coming years.
Global competition requires continued modernization of production facilities.
Energy-efficiency and using new materials, e.g. carbon-composites, require continued retooling of production.
Growing consumer markets require expansion of production capacities.
Decline in products' life cycle and an increase in the variety of products require flexible automation.
Continuous quality improvement requires sophisticated high tech robot systems.
Robots improve the quality of work by taking over dangerous, tedious and dirty jobs that are not possible or safe for humans to perform.
Small and medium sized companies will increasingly use industrial robots.

The increase in supply and demand in industrial robotics signals the steps of an industrial revolution.

INDUSTRY 4.0

The goal of Industry 4.0 is not different from the previous industrial revolutions. It is basically achieving mass production with the help of new technologies. Obviously, in this sense, technology is the fuel for an industrial revolution. This is in fact a cyclic development. Technology helps industries and industries create a need for technology. Furthermore, the path for achieving efficiency and effectiveness in industries sets goals and creates a necessity for technology.

Smart production is at the core of Industry 4.0 (Erkollar and Oberer, 2016). The motto set by Germany Trade and Invest (GTAI) for Indutrie 4.0 is "Smart Manufacturing for the Future" (Germany Trade and Invest, 2014). According to the policy document (Indutrie 4.0 - Smart Manufacturing for the Future), smart industry or "Industrie 4.0" is the technological evolution from embedded systems to cyber-physical systems. It also makes way to a paradigm shift from centralized to decentralized production.

Naturally, Industry 4.0 benefits from various trend technologies. These trend technologies are in fact information technologies (IT) not originally developed and intended for Industry 4.0. These trend technologies are:

- Internet of Things (IoT)
- Cloud Computing
- Big Data
- Robotics and Artificial Intelligence (AI)

These technologies are commonly accepted as the core technologies supporting Industry 4.0. There are also various other technologies such as 3D printing.

European Union and especially Germany is pushing forward the Industry 4.0. Germany is one the most important manufacturers of the world and leader in many aspects related to manufacturing. Much has written about Industry 4.0 and its promises. Therefore, we focus on Industry 5.0 discussions and the critiques of Industry 4.0.

CRITIQUE OF INDUSTRY 4.0

The discussions about Industry 5.0 before the widespread realization of Industry 4.0 clearly indicate the inadequacies of current Industry 4.0 or similar industrial concepts. The definition and the concept of Industry 4.0 is set forth by a set of visionaries including industry experts and academics. The concept was developed as a result of a series of meetings and discussions. In this aspect, there is a top down approach in this so-called revolution. It is possible to argue that a bottom up approach is also required. For example, a study indicates that currently small to medium enterprises (SMEs) find Industry 4.0 irrelevant (Maier and Student, 2015).

Various scholars also approach Industry 4.0 with skepticism (Hirsch-Kreinsen et al., 2016; Sachsenmeier, 2016). First, they question the feasibility of the revolution. The cost to deploy the mentioned technologies such as IoT, robotics, and big data is high for many businesses in many industries. SMEs are in a disadvantage compared to big corporations. Note that in many industries SMEs have a crucial role. There is also the fear of negative social consequences (Hirsch-Kreinsen et al., 2016). Many people may be out of jobs due to increased automation. On the other hand, industrial innovations create new job possibilities. The number of new jobs should be higher than the number of job losses. Otherwise, the public perception towards the new industrial revolution will be negative.

According to some, Industry 4.0 concept lacks innovation. They argue that it is the same stuff with a different packaging. The concept of IT-supported production was already the basis for the previous industrial revolution. Therefore, they claim that there is nothing new about supporting the industry with new information technologies.

The increased use of information technology in industry will create heavy dependency on the IT sector. IT companies will get richer, bigger, and powerful. This creates a certain level of fear among some. On the other, IT companies were becoming powerful regardless of the industrial development. Since

people use IT for many purposes especially in their daily routines. As various industries and IT evolve, implications on each other will be not be predictable. The fear towards unknown is natural.

There are also concerns related to increased autonomy of robotic systems. Experimental autonomous vehicles are on the roads. Unmanned aerial systems are occupying the skies. While such autonomy in robotic systems is exciting, it also raise a variety of concerns among the public. Safety and invasion of privacy are at the top of the list.

IT companies gather enormous behavioral data for various purposes. Even when the intention is good and economic, the end result may not be so harmless for the people. Zuboff (2016) criticize such business behavior and call it "Surveillance Capitalism".

Sachsenmeier (2016) states that the definitions related to Industry 4.0 and similar concepts are incomplete. These concepts clearly need more development before they become an actual industrial reality. Sachsenmeier (2016) claims that these types of concepts and their implementations follow a well-known path. First, they are born with limited scope. Then, these concepts are bought and enlarged by various stakeholders such as political, academic, consulting, and business players. The concept is shaped according to the agendas of these players. The increased use of the word "transformation" is observed during related discussions (Sachsenmeier, 2016). However, these concepts have not yet impacted the actual businesses and society. According to April 2016 findings by the German Allensbach Institute, the public attitude towards Industry 4.0 has shifted from indifference to mistrust (Sachsenmeier, 2016).

An investigation into the 64 papers presented in the 10th Asia Pacific International Conference on Information Science and Technology (APIC-IST 2015) held on July 2015, at Da Nang, Vietnam, showed that most researchers focused on internet of things (IoT) and wireless sensor networks in their studies (Chung and Kim, 2016). 3D Printing, Sharing Economy, Driverless Cars, Nanotechnology, and Biotechnology did not get enough attention from researchers. Chung and Kim (2016) suggest that we need to focus on a diverse research agenda for achieving the fourth industrial revolution.

Increase in mass production seems to be the center and goal of the Industry 4.0. With its current definition, the main inadequacy in Industry 4.0 seems to be the lack of environmental considerations. According to Rada (2017), sustainability and waste prevention should be at the center of the vision for Industry 5.0. Sustainability is also at the heart of the bioeconomy vision of the European Commission. Bioeconomy is expected to have a deep impact on businesses and industries.

INDUSTRY 5.0

There are various different visions for Industry 5.0. Some futurists argue that while Industry 4.0 is essentially about connecting devices together, Industry 5.0 is about collaboration between humans and machines on the factory floors (Johansson, 2017). Gotfredsen (2016) lists the benefits of a collaborative man and machine workforce. There will be a creative human touch on the production instead of a standard robotic production. New jobs will be created. Human workers will assume better roles on the factory floor. According to Østergaard (2016), Industry 5.0 is the return of the human touch on the factory floors. Rendall (2017) argues that while Germany leads the fourth industrial revolution, North America is uniquely positioned to lead the next industrial revolution – Industry 5.0. Rendall (2017) and many others share the vision of man-machine collaboration for the Industry 5.0. There are many discussions and posts on the internet related to Industry 5.0. However, Johansson (2017) argues that two industrial revolutions so close to each other may actually be treated as one. Therefore, Industry 4.0 may incorporate both connectivity and man-machine collaboration (Johansson, 2017). We also share the view of Johansson (2017). One of the pillars of Industry 4.0 is robotics and AI. A natural extension of robotics and AI is man-machine collaboration. Just the introduction of

human-machine collaboration on the factory floors falls short for supporting the case for a new industrial revolution.

According to Sachsenmeier (2016), Industry 5.0 is related to bionics and synthetic bionics. Bionics is "the imitation or abstraction of the inventions of nature" (Sachsenmeier, 2016). According to European Commission (2012), bioeconomy is

> The production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. Its sectors have a strong innovation potential due to their use of a wide range of sciences (life sciences, agronomy, ecology, food science and social sciences), enabling and industrial technologies (biotechnology, nanotechnology, information and communication technologies (ICT), and engineering), and local and tacit knowledge.

Bioeconomy is crucial in achieving a sustainable economy (Schütte, 2017). Smart use of biological resources for industrial purposes will help to achieve a balance between ecology, industry, and economy. German Federal Government gave a priority to bioeconomy in the national research policy agenda when the government adopted the "National Research Strategy BioEconomy 2030" in 2011 (German Federal Ministry of Education and Research, 2011). In the research agenda, five fields of action are given priority. These are

- Securing global nutrition,
- Ensuring sustainable agricultural production,
- Producing healthy and safe foods,
- Using renewable resources for industry,
- Developing biomass-based energy carriers.

Bioeconomy is important for Europe. It has an annual turnover of 2 trillion Euros and 22 million people under employment. According to Schütte (2017) biologization, the guiding principle of the bioeconomy, has the potential to create a fundamental change in industry. Therefore, bioeconomy should be a central part of next industrial revolution.

Another vision for Industry 5.0 is set forth by Michael Rada (Rada, 2015; Rada, 2017). Rada states that the priority of Industry 5.0 is "to utilize efficiently workforce of machines and people, in synergy with the environment. It goes back from a virtual environment to a real one." He also provided a definition for industry 5.0 (Rada, 2017). The theme of this vision is Industrial Upcycling. This vision focuses on waste prevention. Furthermore, Rada points out that we need to turn to human element in the manufacturing process. He criticizes the current digitization trend that is the effort to embed 1s and 0s into any living organism (Rada, 2015).

According to Rada, Industry 5.0 includes 6R methodology and L.E.D. principles. The 6R are:

1. **Recognize:** First, we need to recognize the opportunities offered by Industrial Upcycling. An awareness is the first required step.
2. **Reconsider:** We need to evaluate and reconsider our business and manufacturing processes. A redesign of processes to realize the benefits of Industrial Upcycling is an essential step.

3. **Realize:** After recognition of the opportunities and reconsideration of business processes, we need to realize the business process improvement or innovation.
4. **Reduce:** Reducing the use of resources to achieve efficient outcomes is the essence of the methodology.
5. **Reuse:** Reusing the materials considered as useable prior to process improvement is also at the center of the methodology.
6. **Recycle:** Recycling as much as possible is one of main expected outcomes of the Industrial Upcycling effort. Naturally, the ideal is the zero waste.

6R methodology actually defines a business improvement model. Depending on the specific case, it can be considered as a business process improvement or a business process innovation. Therefore, the 6R methodology is subject to the rules, assumptions, and dynamics of process improvement efforts.

L.E.D. stands for Logistics Efficiency Design. It is designed for global supply chain efficiency improvements. Its goal is to eliminate the waste created by the current modern standard buyer-supplier business relations. L.E.D is the concurrent application of transparency, profit sharing, and efficiency in the supply chain (Rada, 2017).

Four types of waste are identified in Industrial Upcycling. These are physical waste, social waste, urban waste, and process waste.

Physical Waste: The actual physical waste introduced during and after the production. It is basically the trash.

Social Waste: It is the unused potential of the manpower. People unemployed is at the heart of social waste.

Urban Waste: This type of waste includes brownfields, empty spaces, and inadequate infrastructure.

Process Waste: Overproduction, overstocking, empty transport vehicles on the roads are among the process waste.

According to Rada, Industry 4.0 focus on best quantity and mass production. However, the focus of Industry 5.0 is a higher life standard and creativity with high quality custom made products. The theme of Industry 5.0 is simply sustainability. Note that in recent years many companies started programs for green manufacturing and production. Furthermore, they focus on social responsibility projects. The awareness for environmental protection is increasing among people. Customers begin choosing products developed by companies promoting green production.

In table 2, we provide a comparison of Industry 4.0 and Industry 5.0. Note that both industrial revolutions have yet to occur. This comparison is based on the current discussions. The actual revolutions may be quite different than what is actually discussed. A quick analysis of the comparison shows that industry 5.0 will have a wider and deep impact on society.

Table 2. Comparison of Industry 4.0 and Industry 5.0

	Industry 4.0	**Industry 5.0**
Motto	Smart Factory	Bioeconomy
Motivation	Mass Production	Sustainability
Power Source	Electrical power - Fossil based fuel - Renewable power sources	Electrical power - Renewable power sources
Involved Technologies	- Internet of Things (IoT) - Cloud Computing - Big Data - Robotics and Artificial Intelligence (AI)	- Sustainable Agricultural Production - Bionics - Renewable Resources - Human Robot Coordination
Involved Research Areas	- Organizational Research - Process Innovation and Improvement - Business Administration	- Agriculture - Biology - Waste Prevention - Organizational Research - Process Innovation and Improvement - Business Administration

DISCUSSION AND CONCLUSIONS

Industry 4.0 is still in its early stages. It is officially introduced in the beginning of 2010s. In only a few years, various visionaries started discussing Industry 5.0. Moreover, these visionaries also point out the inadequacies of Industry 4.0 and propose Industry 5.0 to overcome the shortcomings of Industry 4.0. One logical conclusion is that Industry 4.0 was introduced without adequate vision. Previous industrial revolutions occurred naturally unlike Industry 4.0, which is formally defined and forced upon the industry. It is possible to argue that this artificial revolution start is premature and proposed without adequate maturity. To call a concept an industrial revolution, we need to observe a widespread change both in industries, businesses, and society. Currently, with its current definition, Industry 4.0 should actually be a proposal. It is clear that Industry 4.0 is still under development.

Smart mass production seems to be the goal of Industry 4.0. Sustainability is main theme in Industry 5.0 proposals. Actually, they are both inadequate by themselves. Note that sustainability and mass production are not mutually exclusive. Therefore, combining these two goals or themes and redefining the next industrial revolution may be a better approach. As a result, the motto of the next industrial should at least be "sustainable smart production". Furthermore, the next industrial revolution – regardless of its name, version, and definition – should encompass the following technologies and research areas:

- Internet of Things (IoT)

- Cloud Computing
- Big Data
- Robotics and Artificial Intelligence (AI)
- Sustainability and environmental protection
- Bioeconomy
- Waste Prevention
- Business Administration and Organizational Research

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The views and conclusions contained herein are those of the author and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of any affiliated organization or government.

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