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An Overview of Industrial Revolution and Technology of Industrial 4.0

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Abstract
The article presents a complete overview of revolutions in industrial history as well as the Technology of Industry 4.0 and related terms. Industry 4.0 refers to the means of automation and data exchange in manufacturing technologies including Cyber-Physical Systems, Internet of Things, Internet of Service, Big Data and Analytics, Augmented Reality, Autonomous Robots, Additive Manufacturing, Cloud Computing, as well as Simulation. It serves important role to help combined and intelligent machines, man, materials, manufacturing lines and methods across organizational stages to build new types of technical data, systematic and high agility value chains. This paper also discussed strengths, weaknesses, opportunities and threats of Industry 4.0.
Keywords: *Industry 4.0, Revolution, Smart Factory, Smart Product, Technology*

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I. INTRODUCTION

The revolution of industry was characterized by radical changes that put enormous pressure on companies. Each level of industrial history implied several challenges, which had to be comprehended, analyzed and lastly overcome. At this current time, the scenario has remained unchanged. The complexity emerges due to the simultaneous oppositeness and connectedness related to the requirements, which have to be satisfied. In other words, companies have to create and offer top-quality products at the lowest price as well as in the shortest time in order to fulfil the customer expectations and requirements.

In addition, unstable market dynamics provoked by novel social, environmental, economic and technological trends forces enterprises to fight for survival in global markets, which are affected by a fierce competition. Given the situation outlined above, it is by means straightforward that a radical transformation of the total industry is indispensable. Companies have to shape their value chain in a way that allows them to maximize its flexibility, responsiveness and agility. First off, physical and digital structures have to be reorganized under consideration of these principles [1]. The unprecedented situation associated to the industrial context, which is significantly characterized by the presence of the digitalization, draws the beginning of a new industrial era denominated as the fourth industrial revolution.

Industry is facing a historic turning point [2]. In industry 4.0, man, machines and materials communicate with one another via the internet. It means the convergence of industry and Internet technology. Advanced machines allow companies to emprise the potential of digitalization in their production systems and to unlock new business fields. The manufacturing engineering sector have to know how new technologies can be successfully combined for the benefit to the customer. Production processes and supply chains are become more efficient, with advances in productivity and large savings in material and energy. Digitalization goes person in person with the growing importance of platforms for data exchange, customer contact and services. Online function facilitates market access, reduce transportation costs and enable innovative things through new business models.

This greatest event had a spectacular impact on the worldwide industrial scene. As one might expect, nearly all the industrialized nations reacted to the significant occurrence by demonstrating financial commitment into Industry 4.0 related projects. In particular, Germany, which already possesses a stable and competitive industry, has assumed the pioneering role. Anyway, other continents, like Asia and USA, even do not sit on their hands and try to take accurate measures. Before Industry 4.0 revolution, there were three prior industrial revolutions that have led to changes of paradigm in the domain of manufacturing: mechanization through water and steam power, mass production in assembly lines and automation using information technology [3].

II. THE FOUR INDUSTRIAL REVOLUTIONS

The first industrial revolution induced a crucial turnaround of the human history that altered nearly every aspect of the daily life. Starting from the year 1760 up to 1840 production environments and in particular manufacturing was destined to undergo profound changes [4]. The first country that passed from an agriculture related economy to an industrial one was Great Britain followed by several European countries like Belgium, France and Germany [5]. Since the dawn of the revolution, it has been clear that the industrialization will affect features, which at first glance could seem not significantly related to the technological realm. Two respective examples, which are represented by socioeconomic and cultural features can be mentioned. The technological variation comprised mainly the usage of new elementary materials and innovative types of energy sources, which can be classified into fuel and motive power [6].

Not only materials and energy sources, but also inventions and the new organization of work must be counted to the fundamental pillars of the industrial revolution. Due to the fact that the textile production and trade was dominating the economic landscape of Great Britain, it was the first to benefit from the effects of the revolution [7]. The spinning jenny, the first multiple purpose spindle machine for spinning cotton or wool, and the so-called "factory system", which initiated a labour division and the resulting specialization of work, gave life to the first modern industry [8]. The traditional duty of the worker was modified dramatically through the acquisition of unedited skills that did not include the ability to work with hand tools, but to operate a machine. Nevertheless, other important technical advances in the communication and transport were provoked by inventions such as the telegraph or the radio as well as the locomotive or the steamship. Even if technical concepts were typically noted in history books, it is important to notice that relevant socioeconomic and cultural mutations occurred. In particular, the balance within the society was put into discussion by distributing wealth over a wider range of society levels [9]. The shift from land as a source of prosperity to industry compromised economic privileges as a birthright among the nobility, banking or merchant families and allowed common people to reach actually high level of wealth. In addition, the concentration of working forces around industrialized areas leads to the creation or the growth of cities [10].

After a brief shortfall in innovations in the mid of the 19th century, the industrial realm experienced once again an inventive upturn. In spite of significant similarities with the initial industrial revolution, the second, also known as technological revolution, took place between 1870 and 1914 [11]. This short piece of history was characterized by a new and stronger acceleration of the industrialization process caused by technological discoveries, which include lighter materials, like alloys and synthetics, and the implementation of a new energy source, namely the electricity [12]. Parallel to this development, the machine tool industry evolved and the importance of new theories came to light. Firstly, the scientific management or Taylorism has to be mentioned. It concentrates on the analysis of workflows and the fragmentation of jobs in order to minimize worker skills and learning times [13]. The overall aim is to achieve extraordinary high labour productivity and economic efficiency [14]. The fundamental principles of the Taylorism inspired the famous American entrepreneur, Henry Ford. He assumed a pioneer role in the global industrial scene through the development of a modern industrial system, whose focal point is composed by the principle of standardization. The first assembly lines were constructed within production sites and the fundaments for the future mass production phenomenon were laid [15]. The progress stimulated the dissemination of known transportation and communication technologies, which previously were predestined to a couple of industrial centres and triggered the first wave of globalization. Also, the owning principles of production sites experienced changes that lead to the division of belongings through the sale of ordinary shares to individuals or institutions [12]. The end of the technological revolution is forced by an event that shocked the whole world, which is represented by the First World War. Subsequently, the discontinuity of the industrial revolution was prolonged by the Second World War. However, a few decades after, the industry was able to create the precondition for the following revolutionary step, namely the beginning of the information age. In this period of time firm bases for the information age were built through the realization of transistors. In addition, a highly relevant management philosophy appeared. The Toyota Production System (TPS) is perceived as the forerunner of the lean manufacturing, whose key principles are embodied by value, value stream, flow, pull and finally perfection [16].

During the 20th century, Industry 3.0 arose with the advent of the Digital Revolution which is more familiar compared to Industry 1.0 and 2.0 as most people living today are familiar with industries leaning on digital technologies in production. Perhaps Industry 3.0 was and still is a direct result of the huge development in computers and information and communication technology industries for many countries. From 1970 up to the year 2012, the third industrial revolution, or how experts prefer to term it, the digital revolution, induced the transition from mechanical and analogue technologies to digital ones. Absolutely essential was the diffusion of the digital logic technology, which includes computers and World Wide Web. Another pillar is represented by the mass production, followed by the mass customization, which allows to fulfil customer requirements related to products by utilizing flexible computer-aided tools [17]. The ability to combine successfully variegated elements belonging to the information technology allowed to evolve high-level automation in manufacturing due to programmable logic controllers (PLCs) and robots. The period of the third industrial revolution, similarly to the predecessors saw the birth of a new energy source that is represented by nuclear energy [18].

The last and current industrial revolution is the fourth. The Industry 4.0 era was facilitated through further development in the technological field that comprise the creation of Cyber-Physical Systems (CPS) and its networking, also called Internet of Things (IoT). The distinctive feature of the fourth industrial revolution is the ability through technology to combine digital, physical and biological realms that affect decisively a broad spectrum of industrial disciplines [19]. Figure 1 illustrates the timeline related to the four industrial revolutions. Industry 4.0 has brought change to many professions. People have always been obligated to learn new everyday tasks but now are also compelled to use hi-tech gadgets which are fast becoming the most important factor in their working life. Industry 4.0 is being presented as an overall change by digitalization and automation of every part of the company, as well as the manufacturing process.

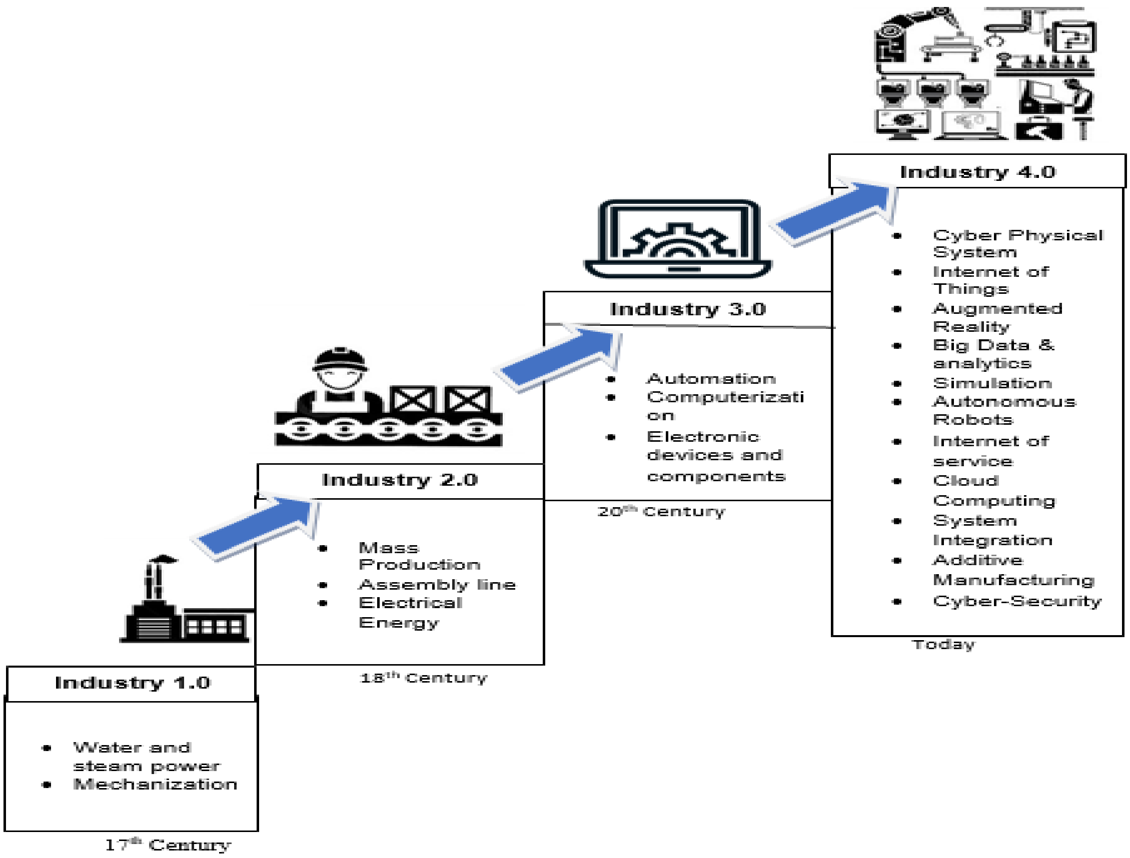

Figure 1: The Timeline of the industrial revolutions

III. DEFINITION OF INDUSTRY 4.0

Industry 4.0 enables the manufacturing sector to become digitalized with built-in sensing devices virtually in all manufacturing components, products and equipment. The analyzing of related data within a ubiquitous system with the fusion of digital data and physical objects has the ability to transform every industrial sector in the world to evolve much faster and with greater impact than any of the three previous industrial revolutions i.e. Industry 1.0,2.0 and 3.0 [20]. Hence, Industry 4.0 is a contemporary issue that concerns today's industrial production as a whole and is meant to revolutionize it. In 2011, Germany introduced Industry 4.0 at the Hannover Fair event, symbolizing the advent of a brand new era of industrial revolution. When the idea was first mooted, extensive efforts were undertaken by the European manufacturing researchers and companies to embrace it. Their interest in this project or concept is due to the fact that under Industry 4.0, production will become more efficient and less costly. This is achieved by easy exchange of information and the integrated control of manufacturing products and machines acting simultaneously and smartly in interoperability [21]. However, different researchers have different perceptions on the true meaning of Industry 4.0. Table 1 shows the different definitions of Industry 4.0 by different authors.

Author and year	Definition
Kagermann , Wahlster & Johannes. (2013)	Industry 4.0 utilizing the power of communications technology and innovative inventions to boost the development of the manufacturing industry [22].
Qin, Liu & Grosvenor (2016)	Industry 4.0 encourages manufacturing efficiency by collecting data smartly, making correct decisions and executing decisions without any doubts. By using the most advanced technologies, the procedures of collecting and interpreting data will be easier. The interoperability operating ability acts as a 'connecting bridge' to provide a reliable manufacturing environment in Industry 4.0. This overall consciousness gives Industry 4.0 the most important aspect of artificial intelligent functions.
Schumacher, Erol & Sihn, (2016)	Industry 4.0 is surrounded by a huge network of advanced technologies across the value-chain. Service, Automation, Artificial Intelligence Robotics, Internet of Things and Additive Manufacturing are bringing in a brand new era of manufacturing processes. The boundaries between the real world and virtual reality is getting blurrier and causing a phenomenon known as Cyber-Physical Production Systems (CPPS) [23].
Schwab (2016)	Industry 4.0 is differentiated by a few characteristics of new technologies, for example: physical, digital, and biological worlds. The improvement in technologies is bringing significant effects on industries, economies and governments development plans. Schwab pointed out that Industry 4.0 is one of the most important concepts in the development of global industry and the world economy [24].
Wang et al., (2016)	Industry 4.0 makes full use of emerging technologies and rapid development of machines and tools to cope with global challenges in order to improve industry levels. The main concept of Industry 4.0 is to utilize the advanced information technology to deploy IoT services. Production can run faster and smoothly with minimum downtime by integrating engineering knowledge. Therefore, the product built will be of better quality, production systems are more efficient, easier to maintain and achieve cost savings [25].
Mrugalska & Magdalena (2017)	The modern and more sophisticated machines and tools with advanced software and networked sensors can be used to plan, predict, adjust and control the societal outcome and business models to create another phase of value chain organization and it can be managed throughout the whole cycle of a product. Thus, Industry 4.0 is an advantage to stay competitive in any industry. To create a more dynamic flow of production, optimization of value chain has to be autonomously controlled.

According to the definition, most of the authors outlined the meaning of Industry 4.0 to consist of key topics related to Cyber-Physical Systems (CPS), Internet of Things (IoT), industrial internet and others. However, some of the authors interested Industry 4.0 on the cost factor and profitability with recently developed high-tech information and intelligent services. From last research on Industry 4.0, beginning the focus was mostly on the sector of industrial production but currently many sectors such as automotive, engineering, chemical, and electronics are beginning to implement Industry 4.0.In summary, Industry 4.0 is aggregating existing ideas into a new value chain which plays a crucial role to transform whole value chains of life cycles of things while developing innovative products in manufacturing which involves the connection of systems and things that create self- organizing and dynamic control within the organization. Industry 4.0 explain a future scenario of industrial manufacturing that is characterized by new levels of controlling, organizing and transforming the entire value chain with the life cycle of products, resulting in highest productivity and flexibility in production through three types of effective integration which are horizontal, vertical and end-to-end engineering integration. Hence, these can predict product performance and autonomously control and optimize product service needs and consumption of resources, then lead to optimization and reduction of costs. Next, aspects of the creation of dynamic, real-time optimized and self- organizing cross-company value networks through the Cyber-Physical Systems (CPS), Internet of Things (IoT), artificial intelligence, additive manufacturing, cloud computing and others are added. All these components are important and are parts of the visionary concept of Industry 4.0.

IV. TECHNOLOGIES OF INDUSTRIAL 4.0

Industry 4.0 is the future of global manufacturing. It is the era of automation, of the digitalized factory and digitalized products – the fourth phase of industrial revolution, or Industry 4.0. Nevertheless, the academics field is still unable to define the approach as the Industry 4.0 is the basic term referring to the fourth industrial revolution. This causes difficulty to distinguish its components. There are 9 technologies of industry 4.0 as shown in Figure 2.

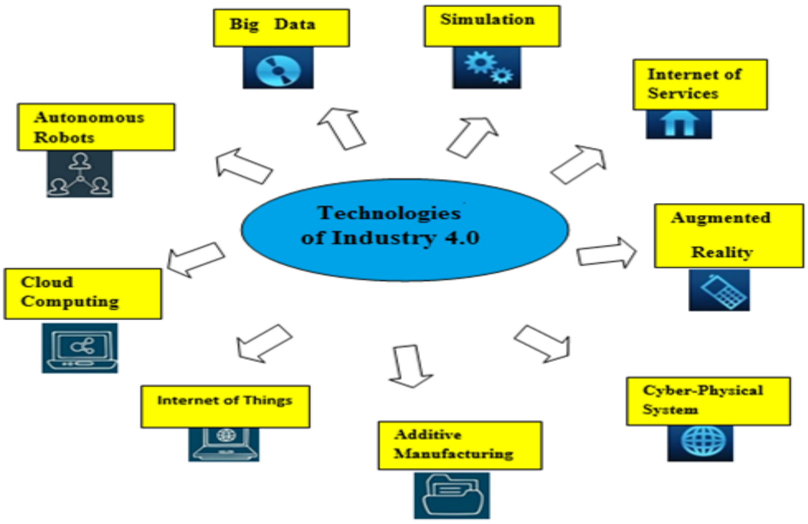

Figure 2: Technologies of Industry 4.0

4.1 Cyber-Physical System (CPS)

Industry 4.0 can be act as a Cyber-Physical System study where the advance logic and speed of development in communication and calculation form the Cyber-Physical System and Industry 4.0. Each manufacturing system of CPS has sensors installed in the entire physical aspects in order to connect the physical things with virtual models. Due to Cyber-Physical System to be more common in society and occurs during interaction with humans, it must be ensured that CPS behave stably and has a certain bearing when utilized with artificial intelligence (AI) [26]. NCPS is also the foundation to create the Internet of Things (IoT) which can be combined to become the Internet of Services (IoS).Hence, businesses will find it easier to establish global networks which joins the warehousing systems, machinery and production facilities of CPS in the future [27].

***4.2* Internet of Things (IoT)**

Industry 4.0 is the new expression for the combination of the present Internet of Things (IoT) technology and the manufacturing industry. Industry 4.0 was initiated as a result of the combination of the Internet of Things (IoT) and the Internet of Services (IoS) in the manufacturing process. IoT can bring advanced connectivity of systems, services, physical objects, enables object-to-object communication and data sharing. IoT can be achieved through the control and automation of aspects like heating, lighting, machining and remote monitoring in various industries [28].

***4.3* Internet of Services (IoS)**

Internet of Services plays as important components in the automotive industry. Activities are affecting through data transfers in the information technology to make daily mobility safer, easier and pleasant. IoS play as service vendors to provide services through the internet according to the types of digitalization services. These things are available and on demand around business concept, partners and any setup for services. The suppliers provide the services into additional value services as communication among consumers can be received and accessed by them through various channels [29].

***4.4* Big Data and Analytics**

In Industry 4.0, big data analytics is useful for predictive manufacturing and is an important direction for industrial technology development through the rapid development of the Internet. This tends to huge number of information produced and obtained daily where current processing and analysis is unable to cope using traditional methods. So, big data has become a hot topic recently in Industry 4.0. Most of other applications would be able to gain additional values when existing techniques become more mature to handle big data. Big data is the utilization of digital technology to conduct analysis. According to Forrester's definition, "Big Data" can be divided into four dimensions which are volume, variety, value and velocity [30].

***4.5* Augmented Reality (AR)**

Augmented Reality has open to be considered as one of the most promising business that technological companies should heavily invest in. This component can bring huge support for maintenance works in business due to reduced time needed for maintenance works and reduction of potential errors in maintenance works. It can predict with high accuracy and allows the frequency of maintenance to be kept at low numbers by utilizing predictive maintenance to prevent any unplanned reactive maintenance. This will reduce costs associated with doing too much preventive maintenance [31].

4.6 Autonomous Robots

Present robots have higher flexibility, advanced functions and are easier to control in multitudes of fields. In the coming future, robots will interact with each other and collaborate actively with humans under the guidance of handlers. These robots will be cheaper and more sophisticated in order to achieve better abilities compared to those currently used in the manufacturing field.

4.7 Additive Manufacturing (3D Printing)

Industry 4.0 is encouraging the utilization of advanced data technologies and smart production systems. Hence, additive manufacturing is one of the important tools to embrace Industry 4.0. The implementation of smart manufacturing skills for the purpose of integrating information technologies plays a important role in the competitiveness of the economy. The advancement of internet technology has encouraged the transition to Industry 4.0. The tendency of looking for new materials available using 3D printing is increasing. Certain required characteristics of a material can be achieved by metallic constituents and smart materials. In fact, the implementation of Industry 4.0 hugely depends on the capabilities of additive manufacturing [32].

4.8 Cloud Computing (CM)

Cloud computing is a relatively new logic system that provides a huge space of storage for the user. A small amount of money allows enterprises or individuals to access these resources. In all time, the performance of technologies keep on improving, however, the functionality of machine data will continue to be stored into the cloud storage system, allowing production systems to be more data-driven. Industry limitations can be reduced since most data sharing will occur across sites for production-related undertakings in the industrial revolution. Cloud computing is slowly considering by many companies during their data systems build. Even if software was traditionally not kept in clouds, the amount of applications being developed in clouds is gradually increasing [33].

4.9 Simulation

Simulation modelling is a way of running a real or virtual process or a system to find out or guess the output of the modelled system or process. Simulations are completed by using real time data to represent the real world in a simulation model, which include humans, products and machines. Therefore, operators are able to optimize the machine settings in a virtual simulated situation before implementing in the physical world. This decreases machine setup times and improves quality. Innovative revolutions in the simulation modelling paradigm enable modelling of manufacturing systems and other systems through the virtual factory concept. Furthermore, advanced artificial intelligence (cognitive) on process control, including autonomous adjustments to the operation systems (self- organization) can also be done through simulations [34].

V. STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS OF INDUSTRY 4.0

However, industrial innovations facilitate the maximization of resources efficiency. Evidently, every enterprise pursues the objective of obtaining the hugest possible output by implementing the lowest possible input. Within the fourth industrial revolution, the advanced governance mechanism enables precise setting adjustment, whose effects are reflected in form of reduced resource consumption. The clearest example can be observed in the reduction of emissions. Production sites are definitely not the only entities that benefit from the changes. The flexibility affects also the human workforce, whose work-life balance quality can be enhanced. The smart work organization and design provides the possibility to form plans, which meets preferences of professionals. The last point belonging to the human sphere, is represented by the emergence of unparalleled career opportunities. In particular, the IT- and engineering realm will experience a positive upswing [35]. Figure 3 summarizes all the mentioned strengths, weaknesses, opportunities and threats of Industry 4.0.

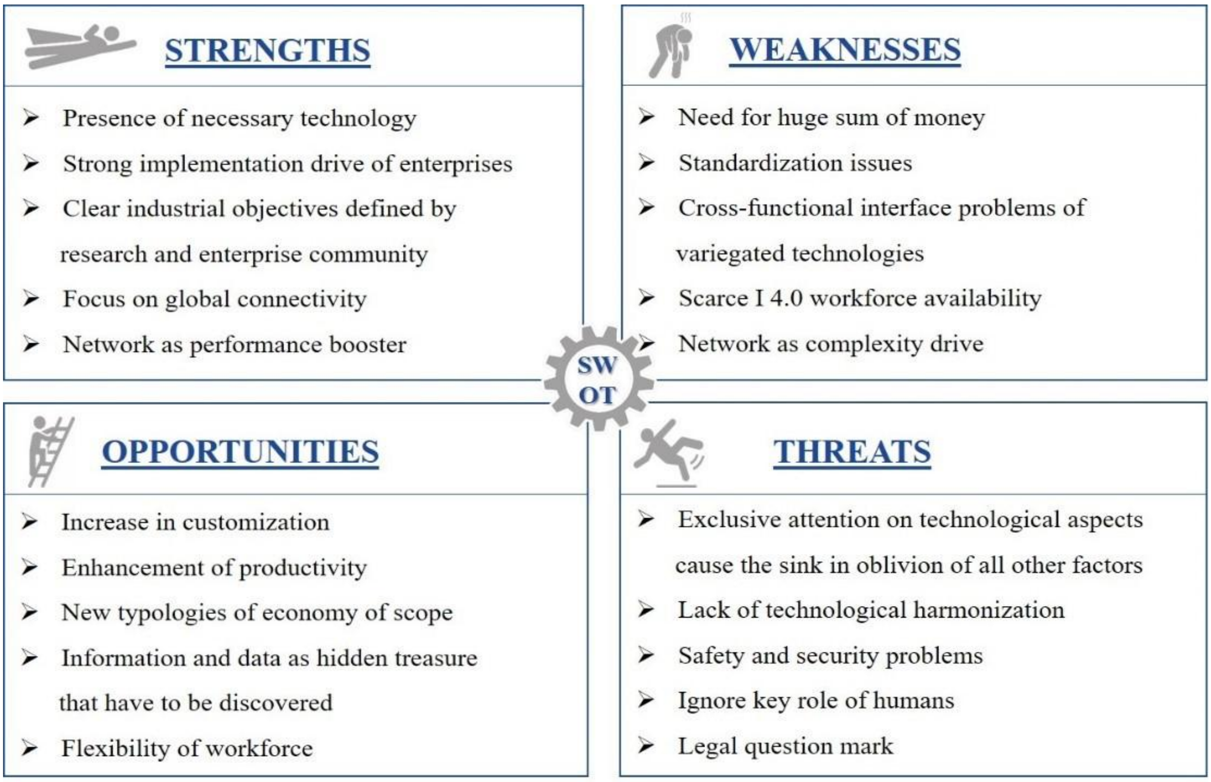

Figure 3: The SWOT-analysis of the industrial 4.0 revolution.

VI. CONCLUSION

This paper focused on providing a thorough overview of the industrial revolution history as well as on the definitions of Industry 4.0 and related terms. In order to accomplish the illustrated step, determinations of renowned institutions as well as experts are taken into consideration. The completion allows passing over to the fundamentals of Industry 4.0, which are treated in detail. Especially, the delineation of concepts like CPS, IoT, IOS, Big Data, augmented reality, Autonomous robots, Additive Manufacturing, cloud computing, and simulation, are incorporated. The presence of a robust level of knowledge permits to concentrate on the individuation of opportunities and threats associated to the last industrial revolution. For each section of the Strengths, weaknesses, opportunities and threats of Industry 4.0 analysis a minimum of five characteristics are underlined.

REFERENCES

[1]. Schumacher, S. Erol und W. Sihn, „A maturity model for assessing Industry 4.0
[2]. readiness and maturity of manufacturing enterprises, " Procedia CIRP, 52, p. 161 - 166, 2016.
[3]. K. Henning, Recommendations for implementing the strategic initiative Industries 4.0, 2013.
[4]. R. Anderl, A. Picard, Y. Wang, J. Fleischer, S. Dosch, B. Klee und J. Bauer, Guideline Industrie 4.0- Guiding principles for the implementation of Industrie 4.0 in small and medium sized businesses, VDMA Verlag GmbH, 2016.
[5]. T. Ashton, The industrial revolution 1760-1830, OUP Catalogue, 1997.
[6]. P. M. Deane, The first industrial revolution, Cambridge University Press, 1979.
[7]. A Nuvolari, „Collective invention during the British Industrial Revolution: the case of Cornish pumping engine, " Cambridge Journal of Economics 28(3), pp. 347-363., 2004.
[8]. N. F. Crafts, „The first industrial revolution: A guided tour for growth economists, " The American Economic Review, pp. 197-201, 1996.
[9]. S. D. Chapman, „The cotton industry in the industrial revolution, " in The Industrial Revolution A Compendium, Macmillan Education UK., 1987, pp. 1-64.
[10]. N. J. Smelser, Social change in the industrial revolution: An application of theory to the British cotton industry, Routledge, 2013.
[11]. M. Syrquin, „Patterns of structural change, " Handbook of development economics, 1, pp. 203-273, 1988.
[12]. J. Mokyr, „The second industrial revolution, 1870-1914, " Storia dell' economia Mondiale, pp. 219-45, 1998.
[13]. Aktenson und P. J. Kehoe, The transition to a new economy after the second industrial revolution (No. w8676), National Bureau of Economic Research, 2001.
[14]. F. W. Taylor, Scientific management, Routledge, 2004.
[15]. S. P. Waring, Taylorism transformed: Scientific management theory since 1945, UNC Press Books, 2016.

[16]. U. Jürgens, T. Malsch und K. Dohse, Breaking from Taylorism: Changing forms of work in the automobile industry, Cambridge University Press, 1993.
[17]. T. Ohno, Toyota production system: beyond large-scale production, crc Press, 1988.
[18]. J. Rifkin, „The third industrial revolution, " International Study Reference, 6, p. 009, 2013.
[19]. J. Greenwood, The third industrial revolution: technology, productivity, and income inequality (No. 435), American Enterprise Institute, 1997.
[20]. J. Lee, . B. Bagheri und H. A. Kao, cyber-physical systems architecture for industry 4.0-based manufacturing systems, "Manufacturing Letters, 3, pp. 18-23, 2015.
[21]. Mrugalska, B. and Wyrwicka, M.K. Towards Lean Production in Industry 4.0. Procedia Engineering 182 (2017) 466 - 473.
[22]. Qin, J., Liu, Y. and Grosvenor, R. A Categorical Framework of Manufacturing for Industry 4.0 and Beyond. Procedia CIRP, 2016, 173 - 178.
[23]. Kagermann, H., Wahlster.W. and Johannes, H. Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0. Forschungsunion, 2013.
[24]. Schumacher, A., Erol, S. and Sihn, W. A maturity model for assessing Industry 4 . 0 readiness and maturity of manufacturing enterprises. Procedia CIRP 52 (2016) 161 - 166.
[25]. Schwab, K. The Fourth Industrial Revolution, what it means and how to respond. Retrieved from https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-howtores pond, 2016.
[26]. Wang, S., Wan, J., Li, D. and Zhang, C. Implementing Smart Factory of Industrie 4.0 : An Outlook,International Journal of Distributed Sensor Networks 6 (2) (2016) 1-10.
[27]. Mosterman, P. and Zender, J. Industry 4.0 as a Cyber-Physical System study Industry 4.0 as a Cyber- Physical System study. Software & Systems Modeling 12 (2) (2015) 1-14.
[28]. He, K.F. Cyber-Physical System for Maintenance in Industry 4.0. Jonkoping University: Master' s Thesis, 2016.
[29]. Zhong, R. Y., Xu, X., Klotz, E. and Newman, S. T. Intelligent Manufacturing in the Context of Industry 4.0 : A Review. Engineering 3 (5) (2017) 616 - 630.
[30]. Buxmann P., Hess T. and Rugabber R. Internet of Services. Business & Information Systems Engineering 5 (2) (2009).
[31]. Witkowski, K. Internet of Things , Big Data , Industry 4.0 - Innovative Solutions in Logistics and Supply Chains Management. Procedia Engineering 182 (1) (2017) 763 - 769.
[32]. Masoni, R., Ferrise, F., Bordegoni, M., Gattullo, M., Uva, E., Fiorentino, M., Carrabba,E. and Donato,M.,. Supporting remote maintenance in industry 4.0 through augmented reality. Procedia Manufacturing 11 (6) (2017) 1296 - 1302.
[33]. Dilberoglu, U. M., Gharehpapagh, B., Yaman, U. and Dolen, M.. The role of additive manufacturing in the era of Industry 4 . 0. Procedia Manufacturing 11 (2) (2017) 545 - 554.
[34]. Xu, X. Robotics and Computer-Integrated Manufacturing From cloud computing to cloud manufacturing Ubiquitous Product Life cycle Support. Robotics and Computer Integrated Manufacturing 28 (1) (2012) 75 - 86.
[35]. Rodič, B. Industry 4.0 and the New Simulation Modelling Paradigm, Organizacija 50 (3) (2017) 193 - 207.
[36]. D. Romero, P. Bernus, O. Noran, J. Stahre und A. Fast-Berglund, „The Operator 4.0: Human Cyber-Physical Systems & Adaptive Automation towards Human-Automation Symbiosis Work Systems, " in FIP International Conference on Advances in Production Management Systems, Cham, 2016.