Industry 4.0"-An Opportunities and Challenges of Implementation

[1]Rugnesh Patel, [2]Harmish Bhatt,

[1]Assistant Professor, [2] Assistant Professor,
[1]Mechanical Engineering Department,
[1]CSPIT-Chandubhai S. Patel Institute of Technology, CHARUSAT, CHANGA, INDIA

Abstract: The globalization and the emerging trend of new world of work are forcing industries to rethink and innovate their production processes. Industry 4.0 involves a wide set of tools & technologies (big data, cloud, robot, artificial intelligence, 3D printing, simulation, etc.) integration into a global network by transmitting digital data. In order to implement such concept requires big investments, while to get benefit from the opportunities offered by the smart revolution, industries must have the prerequisites needed to withstand changes generated by "smart" system. In addition, industries required new surge of agile learners and skilled talent in automation, digitization, and information technology, globally, to meet the challenges of this new era of industry 4.0, Main focus of this paper is to present the essential practices, challenges, and opportunities related to Industry 4.0.

Keywords: **Indusry4.0, Smart Factory, Digitalization, Machine Learning, Internet of Thing (IOT), Robotics, Automation, Smart Production, Artificial intelligence.**

I. Introduction

Industry 4.0 is formerly known as the fourth industrial revolution, a revolution based on the use of Cyber Physical Systems – CPS, the Internet of things (IoT), and the Internet of services (IoS), [1] The fourth industrial revolution is the blending of technologies of the physical, digital and biological world, which creates new opportunities and affects political, social and economic systems, [2] Drivers for moving manufacturing abroad have been reported to include e.g. cost advantages, proximity to customers and requirements for local content [3]. Primary drivers for reshoring manufacturing are reported as a need to improve quality, lead-time and flexibility [4, 5]. Industry 4.0 is a new level of organization that manages and controls the whole value chain of personalized products to satisfy customer needs [6]. Digitalization is the most important element in Industry 4.0 because it allows to connect man and technology [7]. Industry 4.0 covers three fundamental aspects: 1. Digitization and increased integration of vertical and horizontal value chains: development of custom products, customer's digital orders, automatic data transfer, and integrated customer service systems. 2. Digitization of product and service offerings: complete descriptions of the product and its related services through intelligent networks. 3. Introduction of innovative digital business models: the high level of interaction between systems and technology opportunities develops new and integrated digital solutions. The basis of industrial Internet is the integrated and real-time availability and control of systems across the enterprise.

Figure: 1 History of Industrial Revolution

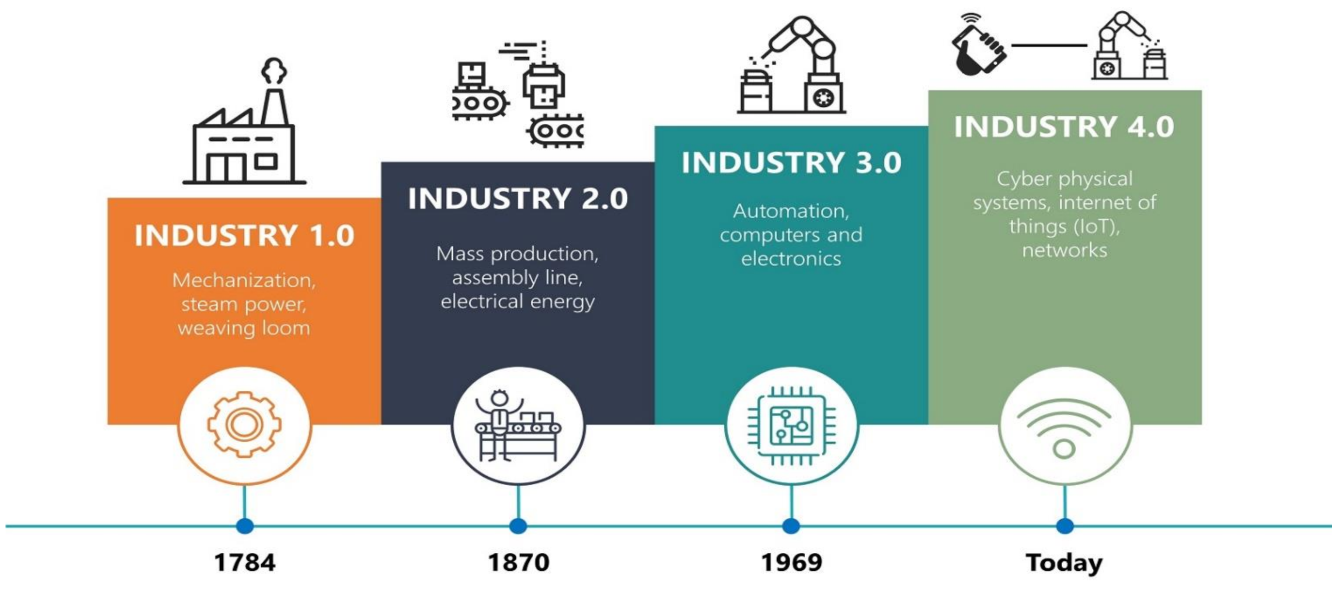


Figure 1 describes the main phases that characterized industrial revolutions. The industrial revolution is divided into two phases: the first industrial revolution, which took place between 1750 and 1850, and the second industrial revolution, which took place between 1850 and 1914.The first industrial revolution led to iron, coal and steam technology, the expansion of railroads and the mass production of textiles. The second industrial revolution, also known as the technological revolution, replaced steam power with electric power, increased steel production and introduced the use of petroleum, all of which greatly improved transportation and led to the inventions of cars, airplanes and electric-powered trolleys and subway trains. In the second half of the 20th century, a third industrial revolution appeared with the emergence of a new type of energy whose potential surpassed its predecessors: nuclear energy. This revolution witnessed the rise of electronics—with the transistor and microprocessor—the rise of telecommunications and computers. In term of partial automation using memory-programmable controls and computers. Now industries able to automate an entire production process—without human assistance through programmable logic controllers (PLCs)—and robots [8]. The fourth industrial revolution characterized by the application of information and communication technologies to industry and is also known as "Industry 4.0". It builds on the developments of the Third Industrial Revolution. Production systems that already have computer technology are expanded by a network connection and have a digital twin on the Internet so to speak. These allow communication with other facilities and the output of information about themselves. This is the next step in production automation. The networking of all systems leads to "cyber-physical production systems" that brings the real world in a virtual reality and therefore smart factories, in which production systems, components and people communicate via a network and production is nearly autonomous [9].

II. State of the art on "Industry 4.0"

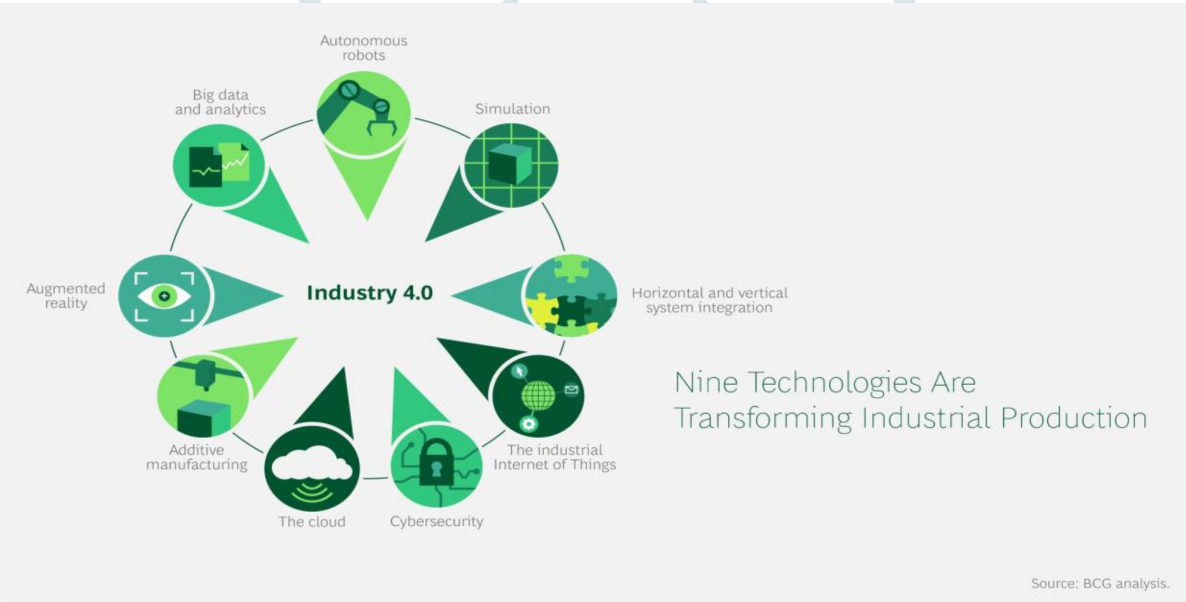
A. Need of industry 4.0

The need of industry 4.0 is to convert the regular machines in to the smart learning machines to improve their overall productivity like performance and maintenance management with the surrounding interaction [10]. Industry 4.0 aims at predictive maintenance, decision-making in real time, anticipating inventory based on production, coordination among jobs [11]. Real time data monitoring, tracking the status and positions of product as well as to hold the instructions to control production processes are the main needs of Industry 4.0 [12].

B. Literature review.

The four main technological drivers of Industry 4.0 are Internet of Things (IoT), Industrial Internet of Things (IIoT), Cloud based manufacturing and smart production which helps in renovating the industrial process into fully digitized and intelligent one [14]. Figure 2. Shows Nine technology pillars form the building blocks of Industry 4.0. This leads to greater efficiency and change in traditional production relationships among suppliers, producers, and customers as well as between human and machine [13].

Figure: 2: Nine Technologies of Industry 4.0 (Source: BCG analysts)



1. Big Data:

In an Industry 4.0 context, the collection and comprehensive evaluation of data from many different sources—production equipment and systems as well as enterprise- and customer-management systems—will become standard to support real-time decision making [13]. As part of Industry 4.0 solutions, industries are compiling systematically produced information like sensor data and location data and then analyzing it to further optimize product planning and production system monitoring. like "The car is a gigantic data-generating machine," says Dieter Becker, an automotive expert at KPMG. "The intelligent linking and analysis of big data will join the art of engineering to become a vital core area of expertise for innovative automakers." Applying this to industry will allow for the collection and analysis of data which can be employed to reduce the creative design times on products, improve logistics, allow for the efficiency comparison across multiple machines in different plants and for improvement where possible as proven necessary from the data gathered [15,16]. Big data can be understood as the convergence of four dimensions, or the four V's: volume, variety, velocity and veracity [17].

2. Autonomous system:

More systems in business are becoming autonomous and need less human intervention to provide effective results [18]. Autonomous Robots will eventually interact with one another and work safely side by side with humans and learn from them. These robots will cost less and have a greater range of capabilities than those used in manufacturing today. An essential face of Industry 4.0 is autonomous production methods powered by robots that can complete tasks intelligently, with the focus on safety, flexibility, versatility, and collaborative. Without the need to isolate its working area, its integration into human workspaces becomes more economical and productive, and opens up many possible applications in industries [19].

Table 1. Autonomous robots used in different industries [20]

	Name of Robot	Company	Function of Robot
1	Canvas Autonomous Cart	Canvas	Flexible and robust material handling solution,
2	SpotMini	Boston Dynamics	Handles objects, climbs stairs,
3	Guardian™ XO®	Sacros	Industrial exoskeleton suit that improves human strength and endurance
4	The WAM® Arm mimics	Barrett Technology	Human-like grace and dexterity.
5	Roberta	Gomtec	6-Axis industrial robot used for flexible and efficient automation

3. Simulation:

Simulations will be used more extensively in plant operations to leverage real-time data and mirror the physical world in a virtual model, which can include machines, products, and humans. This will allow operators to test and optimize the machine settings for the next product in line in the virtual world before the physical changeover, thereby driving down machine setup times and increasing quality [13]. simulation provides the benefits by Identifying manufacturing bottlenecks and opportunities to increase output, identifying cost savings opportunities such as optimization of direct and indirect labor, Validating the expected performance of new or existing production facilities or value streams [21]. simulation optimization provides the "smart brain" required to drastically improve the efficiency of industrial systems [22]. Decision making quality can possibly be improved by easy and fast way with the help of simulations [23].

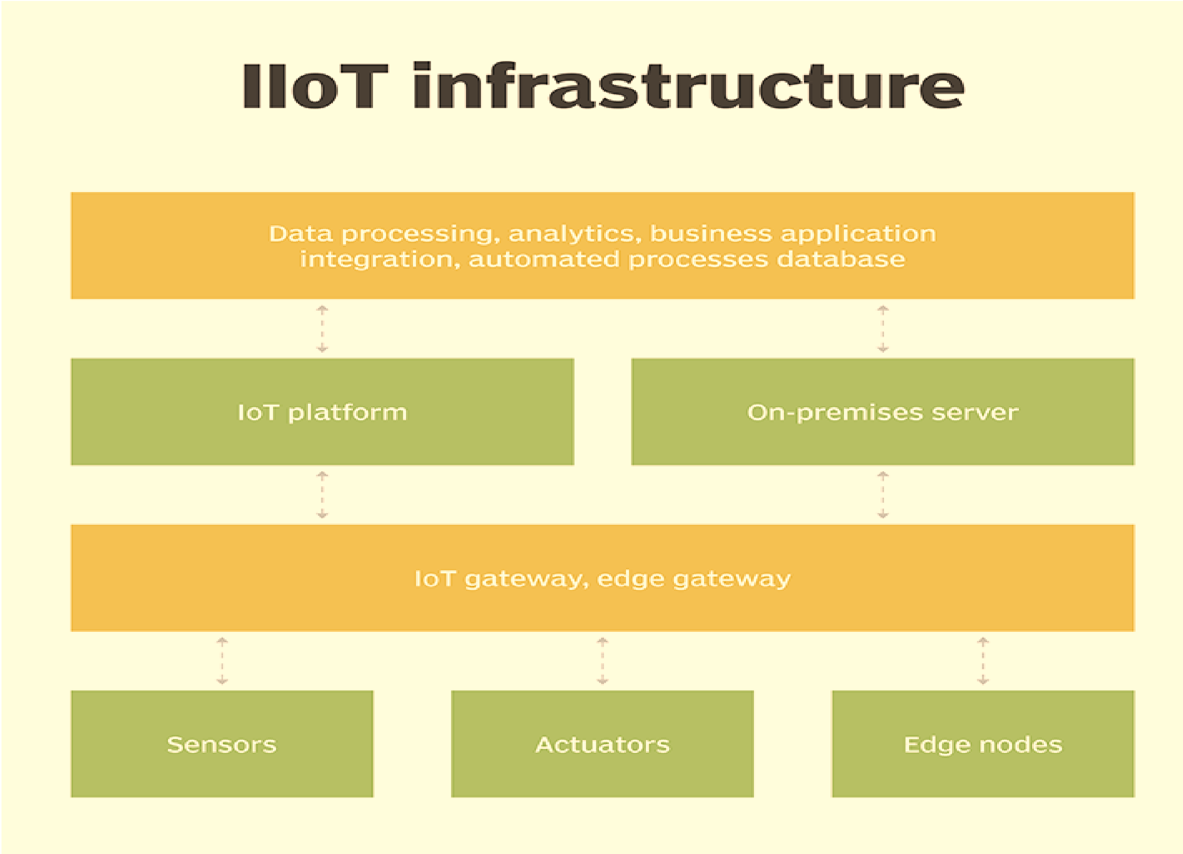
*4. **Universal Integration:** Horizontal And Vertical System Integration:*

With Industry 4.0, companies, departments, functions, and capabilities will become much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains [24]. Integrating Factory Test equipment and a bespoke Manufacturing Execution System can enable remote access and feedback into product test yield, improving projections [18]. The full digital integration and automation of manufacturing processes in the vertical and horizontal dimension implies as well an automation of communication and cooperation especially along standardized processes [14].

5. The Industrial Internet of Things:

Industry 4.0 means that more devices—sometimes including unfinished products—will be enriched with embedded computing. This will allow field devices to communicate and interact both with one another and with more centralized controllers, as necessary. It will also decentralize analytics and decision making, enabling real-time responses [25]. Figure3. The industrial internet of things (IIoT) is the use of smart sensors and actuators to enhance manufacturing and industrial processes. IIoT leverages the power of smart machines and real-time analytics to take advantage of the data that dumb machines have produced in industrial settings for years [26]. The IIoT can greatly improve connectivity, efficiency, scalability, time savings, and cost savings for industrial organizations [27,28, 29].

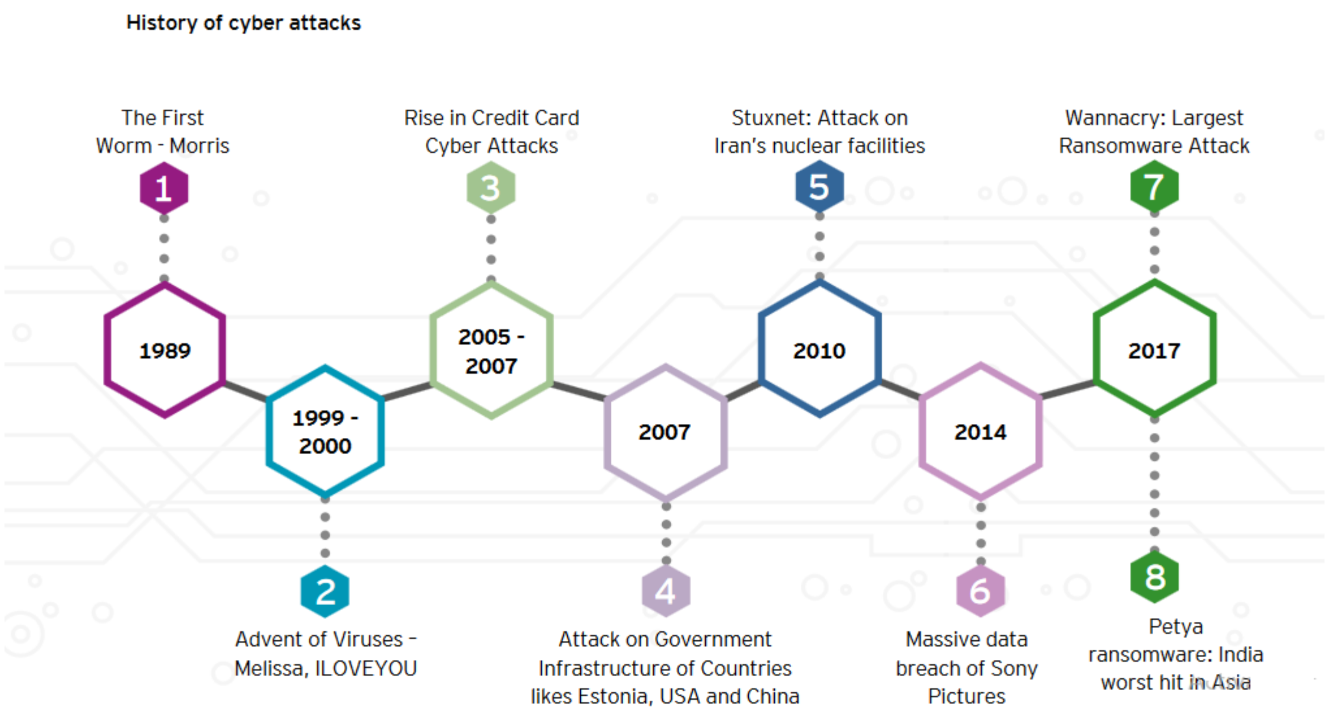
Figure:3 IIoT –Infrastructure (Sources: Tech -Terget)



6. *Cybersecurity:*

With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from cybersecurity threats increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential [13]. As new threats, techniques and attack vectors emerge, the focus of cybersecurity is slowly but surely shifting away from classic perimeter based approach to a 360-degree orientation. This is required to protect hyper-connected systems, network and data of this generation from damages and unauthorized access [30].

Figure:4 History of Cyber Attacks



7. ***The Cloud:***

More production-related undertakings will require increased data sharing across sites and company boundaries. At the same time, the performance of cloud technologies will improve, achieving reaction times of just several milliseconds. As a result, machine data and functionality will increasingly be deployed to the cloud, enabling more data-driven services for production systems [13]. The Cloud facilitates a real-time exchange of data, creating and promoting an environment of digital collaboration and integration. A collaborative supply chain that utilizes the Cloud and the information available will better connect key stakeholders, providing real-time visibility, allowing organizations to proactively manage the supply chain, driving efficiencies and enhancing risk management [31].

8. ***Additive Manufacturing:***

Companies have just begun to adopt additive manufacturing, such as 3-D printing, which they use mostly to prototype and produce individual components. With Industry 4.0, these additive-manufacturing methods will be widely used to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs [32]. Aerospace companies use additive manufacturing techniques to reduce their aircraft weight and raw materials usage such as titanium [13]. It will allow for the onsite creation of tailor made implants for patients that are directly implanted in the patient in the hospital. Nevertheless, this will be only the beginning of AM healthcare applications in the medical world. The most disruptive application of AM therein will be bio printing [32].

Bio printing is understood as the production of (customized) human organs and transplants. Bio printers artificially construct living tissue by outputting living cells layer upon layer in a three dimensional structure. Bio printed tissue is already used in drug intoxication tests nowadays, saving money and the health of test subjects during clinical trials [33]. The production should be faster and cheaper with the use of additive manufacturing technologies like fused deposition method (FDM), selective laser melting (SLM), and selective laser sintering (SLS) [34].

9. ***Augmented Reality:***

Augmented-reality-based systems support a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. These systems are currently in their infancy, but in the future, companies will make much broader use of augmented reality to provide workers with real-time information to improve decision making and work procedures [13]. The world's first augmented reality glasses were launched by Google known as Google Glass; also, Magic Leap was founded in 2011, which adjust to the human eye by converting the light field Angle and depth [35]. This technology enhances human-machine interaction, remoting control on maintenance tasks and visual inspection of the human provided by virtually. It could be used in many applications by combining computer generated graphics and physical objects. AR gives the motion control of its users by using sensor technology in order to control the certain tasks.

III. OPPORTUNITIES AND CHALLENGES IN INDUSTRY 4.0

The Fourth Industrial Revolution, also called Industry 4.0. Major technological advancements are revolutionizing industrial production, where automation of manufacturing processes is upgraded with smart autonomous systems capable of self-cognition, self-optimization, and self-customization. Industry 4.0 will affect all sectors and disciplines, and will have a huge impact on developing countries in particular, where a concentration of low-paid jobs is likely. High-wage jobs will require increased digital skills, and weak education systems in developing countries are often failing to provide basic skills in literacy and numeracy [36]. Industry 4.0 includes concepts, tools and applications that complement a smart embedded system of machines able to communicate with each other and people and perform autonomous tasks in industrial production processes. The main tools include cyber-physical systems (CPSs), the Internet of Things (IoT), big data and cloud computing, autonomous robots, simulation and visualization models, and additive manufacturing [37]. Automation and robotics are perceived as key components – the arms and legs – of Industry 4.0; cameras and other sensors are perceived as the senses; data and connectivity are compared to the nervous system; and artificial intelligence (AI) is the brain.AI enhances industrial processes by enabling the synergetic collaboration between humans and robots in smart factories for mass customization [38]. Industry 4.0 will affect all sectors and disciplines, bringing about a structural transformation in the global economy and leading to a new division of labor, which will have a huge impact on developing countries. A new wave of outsourcing and in-shoring will be triggered, with new technologies, such as additive manufacturing using innovations such as 3D printing, rendering some outsourcing unnecessary. In-shoring could become a new trend in industrialized countries, depriving developing countries of job opportunities [39]. Many predict that Industry 4.0 will cause a polarization of the labor force, with an increasing share of employment in high- and low-wage jobs and a decreasing share of employment in middle-wage jobs. A concentration of low-paid jobs in developing countries is likely, given that high-wage jobs will require increased digital skill sand that weak education systems in developing. Production systems will become more dynamic, flexible, efficient, environmentally sustainable and inclusive through extensive customization and personalization [36]. There will be a decrease in material resources and energy consumption, and new product designs will be introduced that optimize the use of new advanced materials and nanomaterials with beneficial properties, shorten transport routes, and cut transaction costs [40]. Industry 4.0 will also contribute to realizing the circular economy, in which end-of-life products are reused and recycled, and to facilitating the reaping of benefits and opportunities from this. This transformation will also bring with it a change in the nature of jobs, requiring not only increased technical competencies but also interpersonal skills, and will feature remote, flexible and on-demand work [36].

Opportunities of Industry 4.0

- Economic gains, such as increased revenues because of lower transaction and transportation costs,
- More reliable and consistent productivity and output and better quality products
- Shift to mass customization with an increased role for SMEs enabling innovation across many applications, with much larger economic impact on growth,
- Energy-efficient and environmentally sustainable production and systems,
- Effective use of human and material resources Increased food security and safety,
- Improvements in the health and safety of workers Changes in education and training systems,
- More open innovation systems Changes in the organization of work, with more remote, flexible and on-demand work becoming a standard.

B. Challenges of Industry 4.0

- Infrastructure gaps.
- Outdated international rules and regulations that do not take into consideration Industry 4.0
- Standards and interoperability Data ownership and security
- Incentives and obstacles that may shape the development and diffusion of these new technologies (intellectual property protection and others)
- Reliability and stability of CPSs
- Transparency, privacy, ethics and security
- Inequality and exclusion Changes in the very nature of innovation processes and the implication for competition and barriers to entry

IV. CONCLUSION

Industry 4.0 is still a young concept so creating awareness should be the first step and thinking strategically, the second. Companies, governments and society-at-large will need to collaborate to develop a systemic and sustainable model to adapt to Industry 4.0. Countries and companies will need a digital strategy, with education and technical qualifications playing a crucial role. Good ICT infrastructure is needed to help SMEs move into the digital world. Continuous learning and on-the-job training are necessary to develop the new skills required. The new industrial revolution will be characterized by merging of technologies. Among the consequences of "Industry 4.0" and structural problems in the world, economy will be an escalation in competition at the geo-economic level. Industry 4.0 will concur to create new wealth and further improve living standards. The implementation of a 4.0 systems has considerable advantages. Communication should start from high school, through school-work alternation and by providing basic knowledge of computer science and robotics, to make it clear to young workers what is the trend toward which we are moving. Industry, government, and academia will all have roles to play in meeting that challenge a rethinking of what is desired to prepare the new generation for the next industrial revolution Industry 5.0.

REFERENCES

[1] H. Kagermann, J. Helbig, A. Hellinger, and W. Wahlster. Recommendations for Implementing the strategic initiative INDUSTRIE 4.0: securing the future of German manufacturing industry. [Online] Available at: http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Industrie_4.0/Final_ report__Industrie_4.0_accessible.pdf. [Acessed 01-Mar-2017].

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

[3] Stentoft, J., Mikkelsen, O.S. and Johnsen, T. Going local: A trend towards insourcing of production? Supply Chain Forum: An International Journal 16(1), 2015, pp. 2-13.

[4] Barbieri, P., Ciabuschi, F., Fratocchi, L. and Vignoli, M. What do we know about manufacturing reshoring? Journal of Global Operations and Strategic Sourcing 11(1), 2018, pp. 79-122.

[5] Stentoft, J., Olhager, J., Heikkilä, J. and Thoms, L. Manufacturing back shoring: A systematic literature review. Operation Management Research 9(3-4), 2016a, pp. 53-61.

[6] De Felice F, Petrillo A, Zomparelli F. Design and control of logistic process in an Italian company: Opportunities and challenges based on industry 4.0 principles. Summerschool "Francesco Turco"; 2016; Napoli

[7] Varghese A, Tandur D. Wireless requirements and challenges in Industry 4.0. In: International Conference on Contemporary Computing and Informatics; 2014. 634-638

[8] Brettel M, Friederichsen N, Keller M, Rosenberg M. How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. International Scholarly and Scientific Research & Innovation. 2014; 8(1):37-44

[9] Berger R. Think Act: Coo Insight – Industry 4.0. 2014. Available from: http://www.rolandberger.com/media/pdf/Roland_Berger_TAM_COO_Insights_E_20150113.pdf

[10] J. Lee, H.A. Kao, S. Yang, Service innovation and smart analytics for Industry 4.0 and big data environment, Product Services Systems and Value Creation. Proceedings of the 6th CIRP Conference on Industrial Product-Service Systems, Procedia CIRP 16 (2014) 3 – 8.

[11] MAK. Bahrin, MF. Othman, NH. Nor, MFT. Azli, Industry 4.0: A Review on Industrial Automation and Robotic, Jurnal Teknologi (Sciences & Engineering), eISSN 2180–3722 (2016) 137–14321.

[12] F. Almada-Lobo, The Industry 4.0 revolution and the future of Manufacturing Execution Systems (MES), Journal of Innovation Management JIM 3, 4 (2015) 16-21.

[13] M. Rüßmann, M. Lorenz, P. Gerbert, M. Waldner, Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries, (April 09, 2015) 1-14.

[14] S. Erol, A. Jäger, P. Hold, K. Ott, W. Sihn, Tangible Industry 4.0: a scenario-based approach to learning for the future of production, 6th CLF - 6th CIRP Conference on Learning Factories, Procedia CIRP 54 (2016) 13 – 18.

[15] Lee, J. and Kao, H. (2014) 'Product Services Systems and Value Creation Proceedings of the 6 th CIRP Conference on Industrial Product-Service Systems Service innovation and smart analytics for Industry 4. 0 and big data environment'. Available at: (Accessed: 29 January 2019)

[16] Shrouf, F., Ordieres, J. and Miragliotta, G. (2014) 'Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm', in 2014 IEEE International Conference on Industrial Engineering and Engineering Management. IEEE, pp. 697–701. doi: 10.1109/IEEM.2014.7058728.

[17] K. Witkowski, Internet of Things, Big Data, Industry 4.0- Innovative Solutions in Logistics and Supply Chains Management, 7th International Conference on Engineering, Project, and Production Management, Procedia Engineering 182(2017) 763-769.

[18] David Burrell, Senior Consultant, Project Design "Principles of Industry 4.0 and the 9 Pillars" Plextek, Industrial Automation ,7th February 2019.

[19] Roland Berger Strategy Consultants. 2014. Industry 4.0, The New Industrial Revolution: How Europe Will Succeed. International Conference the Next Industrial Revolution Manufacturing and Society in the XXI Century, Turin, November 14 – 15

[20] Mike Thomas, 26 robotics companies changing the way we live and work, Buitin, March 13, 2019, Updated: June 4, 2019

[21] Matt Scanlan "Manufacturing Simulation for Industry 4.0" USA Engineering, Whitepaper,7/3/2018.

[22] Jie Xu et al, Simulation optimization in the era of Industrial 4.0 and the Industrial Internet" Journal of Simulation, Volume 10, 2016 - Issue 4.

[23] G. Schuh, T. Potente, C. Wesch- Potente, A.R. Weber, Collaboration Mechanisms to increase Productivity in the Context of Industry 4.0, Robust Manufacturing Conference (RoMaC 2014), Procedia CIRP 19 (2014) 51 – 56.

[24] T. Stock, G. Seliger, Opportunities of Sustainable Manufacturing in Industry 4.0, 13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use, Procedia CIRP 40 (2016) 536 – 541.

[25] E. Hozdić, Smart Factory for Industry 4.0: A Review, International Journal of Modern Manufacturing Technologies, ISSN 2067–3604, (Vol. VII, No. 1 / 2015) 28-35.

[26] Margaret Rouse, "IIoT use cases put spotlight on IoT benefits, challenges" Essential Guide, IOT agenda Tech target.March 2019.

[27] Inductive Automation: What is IIoT?" The Industrial Internet of Things" July 13, 2018

[28] A. Schumacher, S. Erol, W. Sihna, a maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises, Changeable, Agile, Reconfigurable & Virtual Production, Procedia CIRP 52 (2016) 161 – 166.

[29] A.C. Valdeza, P. Braunera, A.K. Schaara, Reducing Complexity with Simplicity - Usability Methods for Industry 4.0, Proceedings 19th Triennial Congress of the IEA, Melbourne 9-14 August 2015.

[30] https://www.ey.com/Publication/vwLUAssets/EY-cybersecurity-and-the-internet-of-things/$FILE/EY-cybersecurity-and-the-internet-of-things.pdf.

[31] Sébastien Sliski, "Industry 4.0 -Cloud technology within Manufacturing "Compare the cloud.net, 19 July 2018.

[32] Stefan Zimmermann, Industry 4.0 – The Future of Additive Manufacturing, Atos.net March 8, 2018.

[33] T.D. Ngo, A. Kashani, G. Imbalzano, K.T.Q. Nguyen, D. Hui, Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. Composites Part B: Engineering, 143(1):172-196, 2018.

[34] M. Landherr, U. Schneider, T. Bauernhansl, The Application Centre Industry 4.0 - Industry-driven manufacturing, research and development, 49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016), Procedia CIRP 57 (2016) 26 – 31.

[35] He, Z. et al., 2017. Research on Human-computer Interaction Technology of Wearable Devices Such as Augmented Reality Supporting Grid Work. Procedia Computer Science, 107, pp.170–175.

[36] 17th General Confernece UINDO "Industry 4.0 – the opportunities behind the challenge"29 November 2017.

[37] Lee J, Ardakani HD, Yang S, Bagheri B. Industrial big data analytics and cyber-physical systems for future maintenance & service innovation. Procedia CIRP. 2015; 38:3-7

[38] Zhou K, Liu T, Zhou L. Industry 4.0: Towards future industrial opportunities and challenges. In: 12th International Conference on Fuzzy Systems and Knowledge Discovery. 2015. 2147-2152

[39] PwC Strategy. Industry 4.0: Opportunities and Challenges of the Industrial Internet. 2014 Available from: http://www.strategyand.pwc.com/media/file/Industry-4-0.pdf.

[40] Hofmann, E. & Rüsch, M., 2017. Industry 4.0 and the current status as well as future prospects on logistics. Computers in Industry, 89, pp.23–34.