

Industry 4.0: Redefining Manufacturing in Kazakhstan

Sabit Shaiholla*, Asset Bekov*, Ikechi A. Ukaegbu*

*Department of Electrical and Computer Engineering

Nazarbayev University, Astana, Kazakhstan

sabit.shaiholla@nu.edu.kz, asset.bekov@nu.edu.kz, ikechi.ukaegbu@nu.edu.kz

Abstract—The paper analyzes and compares the level of implementation of Industry 4.0 associated technologies in Europe and Kazakhstan. Additionally, possible model of development of manufacturing and implementation of Industry 4.0 technologies in Kazakhstan manufacturing is proposed. The main aim of this project is to define current state of industrial progress in manufacturing in Kazakhstan and compare it with European model. Underlying objective is to propose the model to implement Industry 4.0 in manufacturing in Kazakhstan. As a result, it has been shown that about 80% of manufacturing enterprise in Kazakhstan is on the level of industry 2.0, 17% of the enterprise is on the transitional state between Industry 2.0 and Industry 3.0 and only 3% of all the enterprise is on the level of Industry 3.0. On the other side it can be stated that Europe and particularly Germany shows adequate progress of implementation of Industry 4.0 associated technologies in manufacturing process. Moreover, there are good examples of companies implementing Industry 4.0 associated technologies in manufacturing in Europe shown. So, this paper shows that there is a significant gap in manufacturing process technologies between European and Kazakhstan model, therefore before considering application of European model to Kazakhstan manufacturing process some actions to improve state of manufacturing process in Kazakhstan should be taken.

Keywords— Industry 4.0, manufacturing, process industry, digitization, IT

I. INTRODUCTION

First industrial revolution have lead to use of steam powered machines, followed with usage of electricity for mass production and assembly lines in the second industrial revolution. Third industrial revolution implied digitization of technologies used, usage of computers, internet and information technology.

The current trend in technological progress in the midst of a significant transformation regarding the way the products are being produced through the digitization of manufacturing. This novel approach compromises the integration of cyber-physical systems, Internet of Things (IoT), Internet of Services (IoS), and Smart Factory. Implementation of Industry 4.0 in manufacturing processes involves such concepts as cyber-physical systems, IoT, data analytics and cloud computing. Integration of these technologies into manufacturing process might be challenging, however may lead to huge improvement in manufacturing process and therefore analysis of the market and the way of implementation of Industry 4.0 into manufacturing has crucial importance for every country.

Before analysis of to what extent Industry 4.0 technologies are implemented in manufacturing process in Kazakhstan, current state of manufacturing should be analyzed. According to Ministry For Investments and Development of Kazakhstan (2017) [4] the majority of enterprises in Kazakhstan are significantly lagging in progress compared with European enterprise, and most of them struggling

with implementation of Industry 3.0 in manufacturing process. Thus, this topic is crucial for analyzing, solving and improving industrial situation in the country.

The purpose of this paper is to state current progress in manufacturing in Kazakhstan, state challenges and problems with implementation of Industry 4.0 in manufacturing. Also this paper makes comparison of current state of industry 4.0 implementation in manufacturing in Kazakhstan with European model, and propose possible way of implementation of Industry 4.0 technologies and improvements in manufacturing process in Kazakhstan.

II. CASE STUDY OF MANUFACTURING PROGRESS IN EUROPE

In this section the current progress of Industry 4.0 features on the example of European countries and main attributes that quantify the process of upgrade of industrial stage are underlined and analyzed.

State of art analysis of current technological development in Europe has a leading role in world economy map [3]. The globalization trend is challenged to meet emerging criteria of constantly rising demand for energy, food and social good and concurrently ensuring the sustainability of the level of life per capital. The conceptualization of Industry 4.0 is called to be fundamental foundation in redefining the current trends in industrial progress, including manufacturing. According to Qin, Lui, and Grosvenor (2016) [5], the modern manufacturing processes play an influential role in economical terms in European countries, by accounting for approximately 17% of GDP and creation of workplace for 32 million people. There is a known fact that the term "Industry 4.0" emerged recently in 2011, and therefore there is a lack of established concrete standard for conceptualization of process development under which the current companies might operate. One of the perspective and novel concepts interprets the main design principles of Industry 4.0. Lee, Behrad, and Kao (2014) [6] propound the view that 5C architecture of cyber-physical systems as a part of Industry 4.0 will provide a comprehensive design of advancement and arrange the manufacturing processes. The core idea behind that is the advanced connectivity for real-time data accumulation and deployment, intelligent data management (novel database management systems) and computational capability for inter-operations. Moreover, by drawing on the concept of Industry 4.0, Qin, Lui, and Grosvenor (2016) [5] have attempted to depict the core design concepts behind Industry 4.0, which include interoperability and consciousness. The interoperability is composed from sub-concepts such as digitalization, flexibility and real-time responsibility, whereas consciousness in its turn is composed from predictive maintenance, decision making, self-optimization and self-configuration. The integration of aforementioned concepts comprises the the model of technological shift in terms of Industry 4.0.

The current methods of implementation of basic and fundamental procedural approaches towards Industry 4.0 in European countries (including European Union) include defining the technological

roadmaps and research agendas. As noted by Santos et al. (2017) [7], technology roadmaps is a method of collection of data regarding the technology investment decisions by identifying "evolutionary gaps" in research and development. In other words, the technology roadmaps are used to provide the means and research and development methods via which the gap between industrial progress status can be leveled. It should be noted that despite the fact that European countries are in the vanguard of technological development and adoption of concepts of Industry 4.0, the fully designed implementation of Industry 4.0 is not yet achieved. In the same vein, Qin, Liu, and Grosvenor (2016) [5] note the influential significance of research gap between current manufacturing systems and Industry 4.0. Additionally, they note that the current status of technological development is not comprehensively adopting the full set of features of Industry 4.0, and many companies are working on this area. Together these studies provide important insights into the subject of gap between "industrial revolutions" and the methods to level it in a manner of providing efficient and conceptual methods.

The main driving role of technological developments is accounted on the governmental investments in R&D area. According to PWC's (2016) [9] survey provided, it has been found that global players of industrial progress like Germany, Japan, China and Canada are investing in Industry 4.0 applications for about US \$907 billion annually. In that terms, EU countries are accounted for €243 billion. This trend can be seen on Figure 1 below:

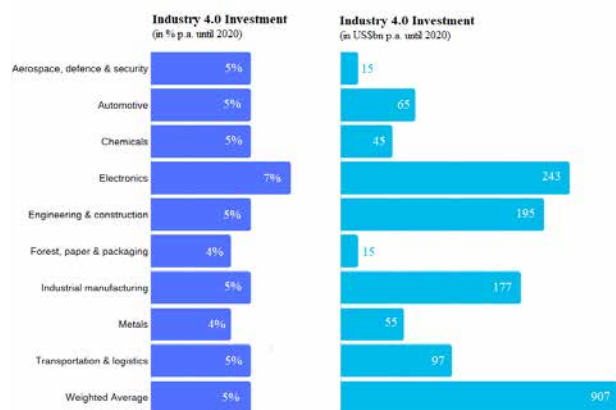


Figure 1: Global trend of annual investments in Industry 4.0 applications[9]

This view of investing in new technological applications are supported by research provided by European Commission (2014) [10]: according to the report provided, the companies that will implement the Industry 4.0 technology could possibly perform for about 10 times better than the companies that do not that implement them, in terms of economical revenue, maximization of cost reduction, effectiveness, efficiency, supply management, and consumer relation. However, more than 41% of European small and medium-sized enterprises (SMEs) do not use these techniques yet.

There are a few real world examples in which manufacturing companies have implemented the most of features of Industry 4.0. One such example is an Audi Company, German automobile manufacturing company. Their vision of implementation of industry 4.0 does lie in conceptualization of smart-factory as foundation for future technological transitions. The backbone of smart-factory operation is the collection and analysis of large volumes of data ("Big Data") which drives the facilitation of manufacturing processes to new level. The process of automobile manufacturing includes the synergy of employees and automated machines, by which they tend to minimize the human effect in assembly line and maximizing the efficiency, flexibility and production rate. Moreover, they plan to use 3D metal

printing to construct the different parts of automobile and deliver them to assembly line via drones, and the whole system will be automated and real-time data driven. Currently, according to latest reviews, Audi managed to transport automobile wheels and tires on assembly line by implementing drones. It is expected that modular manufacturing process would improve the efficiency and production rate of the current process by approximately 20%. Hermann, Pentek, and Otto (2016) [8] provides an insight view of quantitative analysis of design principles of Industry 4.0 scenario models. In this terms, despite being addressed frequently, the real world applied model of Industry 4.0 is still need to be conceptualized and standardized.

III. CURRENT PROGRESS OF MANUFACTURING IN KAZAKHSTAN

Today the upcoming transformation of the manufacturing processes which will radically change the entire technological structure of modern civilization is grasping colossal attention. Regarding the question of when exactly this will take place and which countries will be included in the vanguard of this breakthrough and how exactly it will happen it is difficult to make any predictions as industry 4.0 technologies are still emerging globally in manufacturing with different speed. Despite that, elements and key areas of the new reality are already known, therefore not only the leading but also developing economies of the world already have their own scenarios on how to revolutionize and redefine the industrial sphere. Most of these scenarios include the features of Industry 4.0 which offers a more comprehensive, interlinked, and holistic approach to manufacturing.

In order to depict the state of current industrial progress in Kazakhstan, the technological analysis provided by Ministry For Investments and Development (2017)[4] depicts following characteristics: in manufacturing sector (food stuff, metallurgy, mechanical engineering, etc) approximately 80% of enterprises are at level Industry 2.0 (semiautomated manufacturing), and only 3% of enterprises operate at the level of Industry 3.0. These results characterize that in order to implement the features of Industry 4.0 the aforementioned so-called "evolutionary gap" needs to be covered, which implies the need for flow of investments in this field.

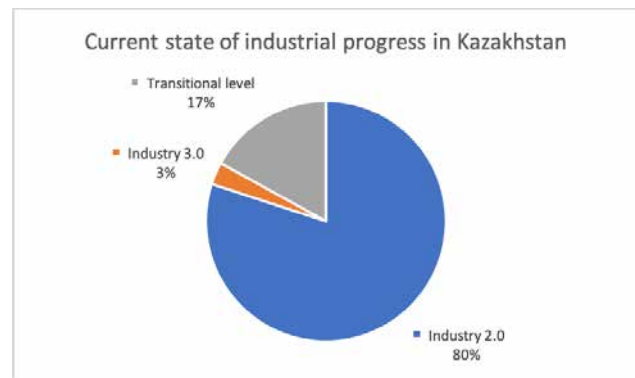


Figure 2: Current state of industrial progress in Kazakhstan

In order to facilitate the industrial progress government of the Republic of Kazakhstan attracts investments and partners for conducting research and development of techniques in the manufacturing and mining sector. "Kazakhstan Industry Development Institute" JSC works with different organizations in order to develop the techniques in manufacturing. From this year "Kazakhstan Industry Development Institute" JSC signed an agreement with "Business-Sweden" and "Fraunhofer Society for the Advancement of Applied Research" [2].

According to the Ministry, within the development of the Set of Measures, a lot of work has been done to attract partners. Foreign

competent partners have been identified for conducting research and development of the Set of Measures in the manufacturing industry and the mining sector.

IV. COMPARISON OF EUROPEAN AND KAZAKHSTAN MODELS

This section describes differences and similarities in current progress in manufacturing process in Europe and Kazakhstan. Additionally the comparison in implementation of Industry 4.0 technologies in manufacturing in Kazakhstan and Europe will be drawn.

There are numerous underlying differences between the current states of industrial progress of European countries and Kazakhstan's one. To start with, as it was mentioned in previous paragraphs, the majority of manufacturing companies in Kazakhstan are at the level of Industry 2.0, whereas in European countries the current industrial progress at the level of Industry 3.0. It has been shown that the current state of progress in European countries are that 41% of European small and medium-sized enterprises (SMEs) are at the level of Industry 3.0. Despite that, there are already examples of implementation of new industrial technologies in worldwide companies such as Audi car manufacturing company. This difference can be explained due to geopolitical conditions restraining the proper technological development in Kazakhstan. One of the major reasons might be the fact that Kazakhstan itself is a new player in geopolitical world map with couple of decades of independence after the disintegration of USSR in 16 December 1991. Despite the active participation in exchanging of experience in industrial sphere with developed countries such as Germany, Great Britain, France and so on, the lack of managing the personnel policy and restraints in development environment could be the main causes of slow adoption of technological developments in Kazakhstan. The main aim of comparison of these two models is to depict the way how European countries are managing to transfer to Industry 4.0 and to use this method as a backbone of the model which will redefine the manufacturing processes in realms applied to Kazakhstan. It should be noted that the conditions at which these two models are being developed differ one from another by numerous reasons which have to be taken into consideration while proposing the new direction of technological development for Kazakhstan's industrial sphere.

V. MODEL OF REDEFINING THE MANUFACTURING

According to the State of the Nation Address by the President of the Republic of Kazakhstan Nursultan Nazarbayev [1], as a part "Development Strategy Kazakhstan 2050" the implementation of Industry 4.0 features would allow to significantly improve the economical and market models of Kazakhstan. Following that, the model of implementation will consist from several objectives such as focusing on the processing sector with high labour productivity, development and test of new instruments aimed at modernizing and digitizing the enterprises, and integrated implementation of information and technology platforms.

To start with, the first main and underlying objective of implementation of features of Industry 4.0 for Kazakhstani companies would be to develop and upgrade the current manufacturing processes to the level of meeting the requirements of Industry 3.0. This innovations would be fundamental factors in transforming the industrial progress to Industry 4.0. Additionally, the enabling elements of new industrial technologies such as IoT platform, cloud computing, advanced human machine interfaces, and Big Data analytics. According to [10] survey, companies are focusing mostly on using data analytics to control and improve their overall business planning and manufacturing operations, followed closely by efforts to get closer to their customers. Additionally, there are other uses of big data analytics which include better service and maintenance of companies' assets and products owned by customers, and better cooperation

and decision-making with partner companies. The importance of implementation of such elements should be emphasized, especially in re-stating the current manufacturing processes in Kazakhstan. By way of explanation, Kazakhstani manufacturing companies will need to use data in predictive, constructive ways that inhibit perception of market developments and customer behaviour to improve products and develop new products and services. In order to specify how this migration might happen, the theoretical case can be analyzed: proposed manufacturing company is implementing the technologies of Industry 4.0 for real-time tracking of manufacturing process, demand, and product supply (supply chain management processes using IoT, CPS), and controlling in real-time the durability and safety of products (production line management using IoT, automation and cloud-computing), and prediction of maintenance processes in advance (predictive maintenance using IoT and Big Data analytics). This theoretical case is positively biased and close to ideal case, whereas in real-world environment the situation might differ hugely due to unforeseen reasons such as fluctuations in market analysis and rapid change of demand production. Despite that, the real-world model should be asymptotically close to ideal case with considerations of numerous elements and nuances relating to the position of Kazakhstan on global map of industrial innovations. To sum up that idea, it can re-stated to be an incremental approach of importing Industry 4.0 technologies in manufacturing processes. Moreover, not all industries have the bandwidth or financial resources to migrate to Industry 4.0 and these entities should consider incremental approaches.

The implementation of aforementioned technologies would require a support from government in terms of investments. As it was mentioned before, the annual investments in Industry 4.0 applications' sector of EU countries are about €243 billion [9]. In order to attract Kazakhstani buyers, the product and/or service pricing should be competitive, clear and transparent. Moreover, this also implies the attraction of foreign investors and companies to invest in Kazakhstani market products to make them profitable and competitive in the global market.

VI. CONCLUSION

As a result current progress of Industry 4.0 technologies implementation in manufacturing in Europe and Kazakhstan were analyzed and compared. Additionally, the model of implementation and development of Industry 4.0 technologies in manufacturing in Kazakhstan has been proposed along with development vector of manufacturing. Europe has a leading role in implementation and defining the direction of Industry 4.0 implementation in manufacturing as the term Industry 4.0 itself was firstly introduced in Germany. The term Industry 4.0 was first introduced in 2011 and there is already examples of companies implementing industry 4.0 technologies in manufacturing in Europe. One of the good examples that has been shown in the paper is the "Audi" company with their conceptualization of smart factory as a foundation for future technological transitions and implementation of big data analytics, cyber-physical systems, automated machines and drones into manufacturing resulting in increasing efficiency of the production process. On the other side, as the term Industry 4.0 has been introduced quite recently there are still no common standard for conceptualization of the process development, and therefore the direction of implementation and development of Industry 4.0 is different in different companies and enterprises. Majority of manufacturing enterprise is Kazakhstan is on the level of Industry 2.0 and only small portion of enterprise is on the level of Industry 3.0, however Kazakhstan government proposed strategy "Development Strategy Kazakhstan 2050" which targets the development of manufacturing process and implementation of industry 4.0 features into manufacturing process. So comparing the manufacturing process in Kazakhstan and European model it has been shown that Kazakhstan model of implementation industry

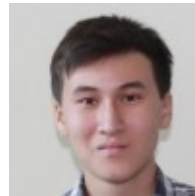
4.0 technologies in manufacturing lags behind significantly and one of the reasons for that can be lack of investments in industrial process development. Thus, one of the proposed solutions for industry development in Kazakhstan is to encourage the development of manufacturing and implementation of new industrial technologies such as big data analytics, internet of things, internet of service and cyber-physical systems with increased investment. Overall it has been stated that implementation of internet of things, big data analytics, cyber-physical systems and other IT and Industry 4.0 associated technologies into manufacturing process would result in increased effectiveness and revenue of manufacturing process, however before the implementation of the above stated technologies, development and upgrade of the current manufacturing processes in Kazakhstan to the level of European manufacturing should be considered. So as it has been shown in this paper the current state of manufacturing process and Industry 4.0 technologies implementation in manufacturing in Kazakhstan significantly lags behind the manufacturing state in Europe, however at the same time there is a considerable potential in the development of manufacturing process and implementation of IoT, Big Data analytics and cyber-physical systems in manufacturing in Kazakhstan. Thus, the possible model of industrial development in Kazakhstan has been proposed.

REFERENCES

- [1] Official Site of the President of Republic of Kazakhstan, "State of the Nation Address by the President of the Republic of Kazakhstan Nursultan Nazarbayev, January 10, 2018". Available: http://www.akorda.kz/ru/addresses/addresses_of_president_poslanie-prezidenta-respubliki-kazahstan-n-nazarbaeva-narodu-kazahstana-10-yanvarya-2018-g
- [2] Kazakhstan Industry Development Institute (KIDI), "From Strategic Consulting to Industry Solutions", 2018. Available: <http://kidi.gov.kz/>
- [3] Muscio, Alessandro, and Andrea Cifollilli, "Industry 4.0: a redefinition of European manufacturing", 2017. Available: https://www.researchgate.net/publication/313554302_Industry_4_0_a_redefinition_of_European_manufacturing
- [4] Ministry For Investments and Development, Republic of Kazakhstan, "Technological analysis of readiness of implementation of technologies of Industry 4.0.", 2017. Available: <http://mid.gov.kz/ru/news/40-predpriyatiy-gmk-kazahstana-imeyut-bazu-k-vnedreniyu-tehnologiy-industrii-40>
- [5] Qin, Jian, Ying Liua, and Roger Grosvenor, "A Categorical Framework of Manufacturing for Industry 4.0 and Beyond", *Procedia Cirp* 52, pp. 173-178, 2016. doi: 10.1016/j.procir.2016.08.005
- [6] Lee, Jay, Behrad Bagheri, and Hung-An Kao, "A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems", *Manufacturing Letters* 3, pp. 18-23, 2015. doi:10.1016/j.mfglet.2014.12.001
- [7] Santos, C., A.Mehrsai, A.C.Barros, M.Araújo, and E.Ares, "Towards Industry 4.0: an overview of European strategic roadmaps", *Procedia Manufacturing* 13, pp. 972-979, 2017. doi: 10.1016/j.promfg.2017.09.093
- [8] Hermann, Mario, Tobias Pentek, and Boris Otto, "Design principles for industrie 4.0 scenarios", in *System Sciences (HICSS), 2016 49th Hawaii International Conference on*, pp. 3928-3937, IEEE 2016. doi: 10.1109/HICSS.2016.488
- [9] PWC, "2016 Global Industry 4.0 Survey: Building the digital enterprise", 2016. Available: <https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf>
- [10] European Commission, "Definition of a Research and Innovation Policy Leveraging Cloud Computing and IoT Combination", 2014. Available: <http://ec.europa.eu/DocsRoom/documents/9462>



Sabit Shaiholla was born in Almaty, Kazakhstan on 28th December 1996. Currently pursuing the bachelor's degree in Electrical and Electronic Engineering in Nazarbayev University, Astana, Kazakhstan.



Asset Bekov was born in Karaganda, Kazakhstan on 26th April 1997. Currently pursuing the bachelor's degree in Electrical and Electronic Engineering in Nazarbayev University, Astana, Kazakhstan.



Ikechi Ukaegbu (M'12) received his B.Sc. in Electrical Engineering, Electro mechanics and Electrotechnology at Moscow Power Engineering Institute (Technical University), Moscow, Russia in 2004 and M.Sc. in Electronics and Microelectronics at the same university in 2006. He obtained his Ph.D. at Korea Advanced Institute of Science and Technology (KAIST) in 2012. He has worked as a Post-Doctoral researcher in Electrical Engineering Department at KAIST from 2012 to 2013. He held R&D positions

at Electronics and Telecommunications Research Institute (ETRI), Korea, from 2008 to 2009 and at Lightron Fiber-Optics Inc., Korea in 2013. He also worked as a senior engineer with the design technology team at Samsung Electronics Co. Ltd, Korea from 2013 to 2016. He co-founded a startup company where is served as the CTO from 2016 to 2017. He joined Nazarbayev University School of Engineering in 2018 and he is currently an assistant professor with Electrical and Computer Engineering Department. His research interests include 5G Technologies, Electronics & Nanophotonics, Signal & Power Integrity, Channel Modeling, and Terahertz Chip-to-chip links. More information can be found at www.idslab.info