Industry 4.0

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Abstract. The information era has caused a leap in the industrial world. Industries that make full use of information technology are known as Industry 4.0, whose upstream and downstream focus on automation. However, in various aspects, there are gaps. Therefore, the use of accurate information is necessary to draw a common thread between various matters related to Industry 4.0. This paper reveals a little through the literature review as reliable information. In short, of course, it reveals the importance of understanding the changes that have occurred, a relation between the old industry and the industry 4.0.

1. Introduction

The term Industry 4.0 is not just the buzzword but is a powerful tool that spreads globally and infects all aspects of human life today [1]. Generalization of aspects of Industry 4.0 is in line with globalization [2]. Data has become very important and drives many change activities from upstream to downstream in scientific fields related to Industry 4.0 [3, 4]. The concept and definition of Industry 4.0 focus on the automation of the industrial world [5]. It provides the implementation of Information Communication Technology (ICT) or the digital world as the backbone of its current existence. But different places, different behavior. Then different times, different potentials also. Therefore, these changes as available potentials are none other than the literature that provides indirect direction about Industry 4.0. This paper does not cover the whole literature related to Industry 4.0 but reveals some interests so that the phrase Industry 4.0 becomes a trigger for improving the welfare of human life. It is an initial review of Industry 4.0. Starting from the evolution of the industry and the concept of industry 4.0, and then, it presents some discussion from some related literature.

2. A Review

A review of something is to follow its historical path, tracking related records and documents. The review of industry 4.0 begins with the evolution of the industry, then reveals some concepts about it from literature.

2.1. Industrial evolution

Since prehistoric times man has produced something to meet his own needs [6]. When humans have
established the community, humans develop methods of obtaining food, clothing, household items, and weapons by hand or the help of working animals [7, 8]. Grouping in the community is as a way to protect themselves when it from attack by larger or fierce animals. Naturally, nature and animals have compelled humans to continue to change. It is to improve humans’ identities and welfare. However, conflicting group tendencies have resulted in communities around the world falling deeper and deeper into the abyss due to competition [9]. The presence of good moral behavior has changed the world until humans reach a stage of change [10, 11, 12]. Technology is a means of increasing welfare and helps the existence of an industrial world, where it brings manufacture to meet market demands and advance the economy [13]. Some of the changes have generated leaps and bounds, although not entirely as revolutions. Overall history is evolutionary as follows:

2.1.1. Industry 1.0. Early in the 19th century, there was water and steam-powered machine to partially replace the role of animals in and at the same time help workers [14]. When the production capacity increases, the market must be ready to accommodate productions with outlets. Thus, individual-owned business cottages fill the needs of both themselves and their neighbors. The owners became managers and hired their families as employees to serve customers until several related organizations were forming [15]. Besides social issues, environmental issues have started to be a concern.

2.1.2. Industry 2.0. The main problem in the industrial world, in the beginning, was the easy availability of energy [16]. Early the 20th century, the presence of electricity as the power source has generated a passion for a step of the industry and business worlds newly [17]. The new machines were designing to be more portable. By technology, vehicles, ships, trains, and some devices that are driven by machines, where machines use oil, so attention to the environment becomes an obstacle, and the damage is always easier than environmental restoration [18].

The new administrative model for this stage has now developed several management programs that allow the efficiency and effectiveness of the manufacturing facility, that is, the division of labor into interconnected stages, assigning workers according to that stage. Every job is approached optimally with and perfecting work procedures so that the quality is even better. Thus, the mass production of goods involving the assembly line has been part of this second chance. This administrative model also tries to answer environmental issues by maximizing the use of natural resources [19].

2.1.3. Industry 3.0. Following the succession of the presence of electricity, new inventions have given rise to the presence of electronic devices. Transistors have replaced vacuum tubes, then immigrated electronic circuits into integrated circuit chips [20]. Initially, computation tools were limited to makeshift calculations, such as the abacus, and later calculators. Machine after the machine, however, was updating its performance, so that presence a machine could fill with customizable programs according to the user’s interests [21]. Thus, it is possible to automate mechanical things. Such as, the typewriter was slowly later replaced by a computer, it saves paper usage and reduces several environmental issues, forests.

The integration of computers with machine tools began to occur, allowing planning to meet raw materials, finding replacement resources, scheduling work, tracking production flow. Administratively, the ever-expanding spread of geographic reach reveals the importance of the supply chain. Along with the relocation of factory operations to low-cost regions/countries, and causing social issues, especially labor, always haunt the sustainability of the industry. However, environmental issues continue to be a problem, not only because of the pollution of production machines but as a result of industrial waste and community users [22].
2.2. Concepts and definitions of Industry 4.0
The literature related to Industry 4.0 states that the concept of Industry 4.0 deals with a green vision of machines to address environmental issues [23]. It provides an opportunity to create a smart factory [24] and a chance to enter a new market [25]. That is by involving a computer system whose mechanism is controlled/monitored by the algorithm [26]. So, changes in the concept of the industry have occurred since computers and information technology were present as tools to improve welfare [27]. This technology, driven by the achievements of science, which have implications for the leap of change, has had a profound effect on many other scientific and applied fields [1].

This technology, driven by the achievements of science, which have implications for the leap of change, has had a profound effect on many other scientific and applied fields [1]. The first effect is the automation tendency to operate [28], control [29], and monitor mechanically moving machines [30, 31]. Also, support for integrated data exchange customizes those interests into environmental issues [32]. Information and communication technology (ICT) has developed at a faster pace [27], and this development is always related to the issue of strengthening the economy from the resource side [33], taking into account the concepts of efficiency and optimization [34, 35].

The future vision of Industry 4.0 continues to refine the concept and implementation of automation [36]. Artificial intelligence (AI) to robotics plays a role in facilitating heavy and risky work [37, 38]. Research after research about Industry 4.0 has taken effect. This reality makes Industry 4.0 as a topic of discussion today [39]. The result is not only technology but procedures to advance the skills of the workforce through training and education. Therefore, the latest concept concludes that Industry 4.0, the fourth industrial, is a revolution in production, manufacturing, and industry [40].

3. An Approach
Industry 4.0 has become a phenomenon since the presence of reputable database indexed documents in 2012. Every phenomenon that requires a paradigm as its counterpart and is a solution [41]. Several problems in the industrial world have become a legacy to Industry 4.0, and these problems do not yet have any realization [19, 20, 22]. Study after study provides answers, but there are still empty spaces that have not been filled by the study, especially about the industrial world from developing countries [42]. Industry
4.0 still belongs to high-tech countries while poor and developing countries become waste disposal [43], including old generation factories, which generally produce higher pollution [44].

The fact that covers the industrial world is punishing industrialized countries again with the problem of endless sources of energy. Besides, the gap between the world of work and skilled workers has had a significant impact on Industry 4.0. The importance of studies of Industry 4.0 is to prepare the sides of its problem to become more important in order to get solutions. Therefore, the first fact to be revealing is the growth of scientific publications related to Industry 4.0 is evidence of the studies about it [45]. Facts that show evidence of the study are equivalent to technological developments related to Industry 4.0.

Furthermore, this approach takes advantage of the study to summarize several things from Industry 4.0. First, relating to the issues of Industry 1.0, Industry 2.0, and Industry 3.0, and their transformation into Industry 4.0. Second, the need to briefly organize Industry 4.0 from a technology and education perspective [46]. It is to provide advice to administrators in government, education, and the world of work.

**Table 1.** Research evidence on Industry 4.0 from the reputable database Scopus.

| Index | Year | All | T | Germany | TAK | China | T | Singapore | TAK | United States | TAK | T |
|-------|------|-----|---|---------|-----|-------|---|-----------|-----|---------------|-----|---|
| Inventor | 2012 | 2 | 1 | 2 | 1 |
| Inventor | 2013 | 31 | 21 | 20 | 11 |
| Inventor | 2014 | 93 | 55 | 65 | 36 |
| Inventor | 2015 | 208 | 117 | 122 | 76 | 14 | 5 | 1 | 1 |
| Inventor | 2016 | 547 | 227 | 235 | 105 | 46 | 16 | 4 | 2 | 1 |
| Inventor | 2017 | 1148 | 423 | 312 | 116 | 92 | 34 | 12 | 3 | 2 |
| Inventor | 2018 | 2140 | 779 | 382 | 129 | 110 | 26 | 14 | 4 | 27 | 1 |
| Inventor | 2019 | 4318 | 1215 | 475 | 128 | 289 | 35 | 45 | 12 | 57 | 11 |
| Inventor | Japan | 2012 | TAK | T | 1 |
| Inventor | 2013 | 5 | 2 | 1 | 1 | 2 | 2 |
| Inventor | 2014 | 10 | 8 | 6 | 1 | 3 | 2 |
| Inventor | 2015 | 21 | 5 | 40 | 12 | 13 | 8 | 23 | 3 | 1 | 1 |
| Inventor | 2019 | 34 | 3 | 91 | 29 | 31 | 14 | 191 | 16 | 2 |

**Note:**

TAK = Title, Abstract, Keyword on query where there is “Industry 4.0”

T = Title on query where there is “Industry 4.0”

USU = Universitas Sumatera Utara

4. Result and Discussion

In literature, the first two reputable documents on Industry 4.0 indexed in the Scopus database in 2012 are from Germany [23, 47]. One document makes Industry 4.0 a topic of study [23]. One other document reveals support for Industry 4.0 from different fields [47]. In the following years until 2019, the number of documents about Industry 4.0 has grown following an exponential function, see Figure 1. Studies on Industry 4.0 have become a topic in several countries, such as Table 1. The study of Industry 40 from Indonesia country only appeared in 2018 or 6 years from the first document. Meanwhile, countries such as
China, Japan, and Singapore have one year preceded Malaysia, Thailand, including the United States. Therefore, the response to scientific development through the dissemination of knowledge related to Industry 4.0 depends on the sensitivity of scientists from each country, or it is related to the interests of that country to Industry 4.0 from the government’s side.

The presence of documents, on Industry 4.0 from the country of Indonesia after centuries since the first document, reveals the assumptions [48]: First, related scientists are not responsive to changes that occur in the industrial world [49, 50, 51, 52, 53, 54, 55]. Second, research does not carry out well and runs slowly, so that it is unable to establish communication with foreign researchers [56, 57, 58, 59, 60]. Third, neither the government nor the industrial world is ready to follow these changes [61]. Fourth, both the government and industrialists still want to maintain the old industrial concept [51, 62, 63, 64, 65, 66]. All these assumptions require study and verification. Also in plain view, without the need for data consideration, and of course it has become a fact, as a whole in developing countries, there are not a few industries, that are slow to respond to these changes, this has resulted in manufacturing includes in the previous industrial level [57, 67, 68, 69, 70, 71].

The technology gap between Industry 1.0, Industry 2.0, Industry 3.0, and Industry 4.0 has classified countries in the world according to their level of mastery of related technology. Technology-controlled countries are the main competitors such as Germany and China while developing countries are trying to enter Industry 4.0 by learning strategies and approaches according to their respective interests [72, 73].

Countries that still have Industry 2.0 are moving to Industry 4.0 with a leap of innovative initiatives or innovative initiatives, especially making the university move space to make breakthroughs with adaptation approaches and scientific transformation to support technology transfer [74, 75]. In literature, the adaptation method makes an immediate move from Industry 2.0 to Industry 4.0 [74], while evolutionarily, it is by making preparations, through the fulfillment of a workforce [75].

Countries with Industry 3.0 are a little easier to move to Industry 4.0 by modernizing production and innovative digital creations, especially involving advances in robotics [22, 76]. Some mechanical production is described for Industry 4.0, by connecting that production to appropriate technology humanless and paperless. Modernization slowly carries out from research institutions, especially universities, to ensure the evolution of change to a convincing stage [77]. However, this must be supported by virtual simulations so that the acceleration of the change to Industry 4.0 takes place. On the other hand, automation applies robotics to acquire the capabilities of workers, but robotics is different from industrial robots, which can work collaboratively [78]. Furthermore, preparing specialists who can work and adapt to digital machines. Thus, Industry 3.0 shifts to Industry 4.0.

The concept of Industry 4.0 is a trend of automation in all areas of life to fulfill the needs of human life, be it clothing, food, or comfort, by exchanging the latest data in factory technology. Physically, this produces a “smart factory” by implementing technology, such as designing the intended factory by using Computer-aided design (CAD) to lift high-precision calculations so that the installation and operation of robots will not experience problems. Design is enabling to organize cloud computing so that artificial intelligence can interpret every activity of a smart factory. Design that enables implementing Internet of Thing (IoT) to integrate all sensor devices that monitor the environment, machines, robots, the outside and inside of the plant, every movement, weather, rain, and other potential.

Therefore, research involving the interests of the concept, theory, and implementation of Industry 4.0 continuously carry out, and it accompanies the preparation of experts and skilled personnel in all fields related to Industry 4.0. The latter is the role of higher education institutions as a downstream academician that continuously conducts research [79, 80].

As a case, the Universitas Sumatera Utara, as one of the largest educational institutions in Indonesia, has only touched and discussed Industry 4.0 a little, which is 1.05% of publications from Indonesia in 2019 and only 0.05% of all studies in the world. Of course, developing an educational curriculum to
trigger research in this field is not enough. Therefore, the presence of a study program that focuses on Industry 4.0 is awaiting.

5. Conclusion
Technological advances have led to changes in the industrial world, which, in essence, involves the automation of all sides of its interests. The change affected the old world of an industry that was still moving manually and mechanically. There are two ways to move from old to new industries, by adapting new technology and preparing the related experts, at once. It is only the first step that requires study after further study.

References
[1] S Engleder and Dimmler G 2015 Industry 4.0: A major opportunity and the response to the smart factory Kunststoffe International 105(9)
[2] L D Xu, E L Xu and L Li 2018 Industry 4.0: State of the art and future trends International Journal of Production Research 56(8)
[3] M K M Nasution, I Aulia and M Elveny 2019 Data Journal of Physics: Conference Series 1235(1)
[4] M K M Nasution, O Salim Sitompul and E Budhiarti Nababan 2020 Data Science Journal of Physics: Conference Series 1566(1)
[5] G Culot, G Nassimbeni, G Orzes and M Sartor 2020 Behind the definition of Industry 4.0: Analysis and open questions International Journal of Production Economics 226
[6] P Stanier 1985 The granite quarrying industry in devon and cornwall part one 1800-1910 Industrial Archaeology Review 7(2)
[7] N Gleszer 2008 Orthodox kosher mass culture?: Food industry, hospitality industry, children’s holidays and open-air baths in the weekly paper of orthodox Jewry in Hungary, 1925-1944 Acta Ethnographica Hungarica 53(2)
[8] C Zlohliski 2010 Economic globalization and changing capital-labor relations in baja California’s fresh-produce industry The Anthropology of Labor Unions
[9] L C Twonsend 1984 Japanese Labour Relations and Australian Industry Asia Pacific Journal of Human Resources 22(3)
[10] N Matar 2019 Morgan and Mohamed Rabadan: The first Muslim Biography of the Prophet Muhammad in English Journal of Islamic Studies 30(2)
[11] B Zengin Arslan 2020 Reading the Universe with Heart and Practicing Science as Religious Ethics: Reconciling Islam and Science in Contemporary Turkey Social Epistemology 34(3)
[12] Y Purwanto, E Saepudin, D S Hidayatullah, A Darmana and E A Yani 2020 Islamic character education and nationalism insight of students in the era of industry 4.0. International Journal of Psychosocial Rehabilitation 24(4)
[13] D D Dabi and W P Anderson 1999 Development of a commodity-by-industry economic-ecological model of water demand in a rural economy Journal of Environmental Planning and Management 42(5)
[14] S M Kempegowda and Z Chaczko 2019 Industry 4.0 complemented with EA approach: A proposal for digital transformation success 26th International Conference on Systems Engineering, ICSEng. Proceedings
[15] W S Shin, Y Seok Lee and J J Dahlgaard 2019 A pattern-based decision framework in the era of Industry 4.0 Total Quality Management and Business Excellence 30, Issue sup1
[16] J Willums and S A Franck 1975 Impact of the energy crisis on the future of the rubber and automotive industries Sver Gummitek Foren Publ (46)
[17] Alfred Klimesch 1976 Electricity Industry from the Point of View of the Power Industry as a Whole. [DIE ELEKTRIZITÄTSWIRTSCHAFT IM RAHMEN DER GESAMTEN ENERGIWIRTSCHAFT.] Elektrichesvo 29 (5)

[18] Keller C 1970 Transfer dies in the appliance industry SME, Creative Mfg Semi

[19] V-R Arturo and O G Ivone 2014 The salmon industry 2.0 in Chile: A perspective from the viewpoint of environmental governance [Salmonicultura 2.0 en Chile: Una mirada desde la gobernanza ambiental] Revista Venezolana de Gerencia 19 (65)

[20] P E Haggerty 1968 Integrated Electronics and Change in the Electronics Industry IEEE Transactions on Electron Devices 15(9)

[21] R L Shuey and R L Shuey 1975 Industry and Computers IEEE Transactions on Manufacturing Technology 4 (2)

[22] K H Tantawi, A Sokolov and O Tantawi 2019 Advances in Industrial Robotics: From Industry 3.0 Automation to Industry 4.0 Collaboration TIMES-iCON 2019 - 2019 4th Technology Innovation Management and Engineering Science International Conference

[23] D Hofmann, R Margull, P-G Dittrich and E Du’n’tsch 2012 Smartphone green vision at dawn of industry 4.0 Advanced Materials Research 403-408

[24] M Lewis 2016 Industry 4.0 and what it means to the foundry industry 72nd World Foundry Congress, WFC 2016

[25] D Kotarski 2014 Industry 4.0 - New opportunities mean new challenges [Fabriksicherheit fu¨r industri e 4.0] Productivity Management 19 (3)

[26] J Sztipanovits 2007 Composition of cyber-physical systems Proceedings of the International Symposium and Workshop on Engineering of Computer Based Systems

[27] S Lazarova-Molnar, N Mohamed and J Al-Jaroodi 2018 Collaborative data analytics for industry 4.0: Challenges, opportunities and models Proceedings - 2018 6th International Conference on Enterprise Systems, ES 2018

[28] A Decker 2016 Industry 4.0 and SMEs in the Northern Jutland Region Value Creation in International Business: Volume 2: An SME Perspective

[29] S Hoppe 2014 Forerunner to industry 4.0 and the internet of things Control Engineering 61 (11)

[30] D Spath, O Ganschar, S Gerlach, M H’ammerle, I Jesemann, T Krause and S Schlund 2013 Industry 4.0-manufacturing work of the future survey results 22nd International Conference on Production Research, ICPR 2013

[31] M Pan, J Sikorski, C A Kastner, J Akroyd, S Mosbach, R Lau and M Kraft 2015 Applying Industry 4.0 to the Jurong Island Eco-industrial Park Energy Procedia 75

[32] L T Ha, A D Marques and F Ferreira 2018 How Industry 4.0 concepts are applied in the Portuguese clothing industry: Some evidences IOP Conference Series: Materials Science and Engineering 459 (1)

[33] H Kagemann 2015 Change through digitizationvalue creation in the age of industry 4.0 Management of Permanent Change, 1 January 2015

[34] M Glu’ck and J Wolf 2014 Integrated quality management for industry 4.0 [Produktionsintegrierte qualitats sicherung fr die industri e 4.0] Productivity Management 19(2)

[35] C Neef, S Hirzel and M Arens 2019 Industry 4.0 and the European iron and steel industry: From concept to implementation [Industrie 4.0 und die europishe Eisen- und Stahlindustrie: Vom Konzept zur Umsetzung] Stahl und Eisen 139 (4)

[36] P Kubalczyk 2017 Effects of industry 4.0 on business processes — [Die wirkung von industri e 4.0 auf prozesse] Productivity Management 22 (4)

[37] M Dopico, A Gomez, D De la Fuente, N Garca, R Rosillo and J Puche 2016 A vision of industry 4.0 from an artificial intelligence point of view Proceedings of the 2016 International
Conference on Artificial Intelligence, ICAI 2016 - WORLDCOMP 2016

[38] A Richert, M Shehadeh, L Plumanns, K Gros, K Schuster and S Jeschke 2016 Educating engineers for industry 4.0: Virtual worlds and human-robot-teams: Empirical studies towards a new educational age IEEE Global Engineering Education Conference, EUDCON

[39] M Crnjac, I Ve’za and N Banduka 2017 From concept to the introduction of industry 4.0 International Journal of Industrial Engineering and Management 8 (1)

[40] S Aydin, F Kutlu Gu¨ndogdu 2020 Interval-Valued Spherical Fuzzy MULTIMOORA Method and Its Application to Industry 4.0 Studies in Fuzziness and Soft Computing 392

[41] L Gerlitz 2015 Design for product and service innovation in industry 4.0 and emerging smart society Journal of Security and Sustainability Issues 5(2)

[42] S Saniuk and A Saniuk 2017 Industry 4.0 - Technical-economic development perspective for the metallurgical production METAL 2017 - 26th International Conference on Metallurgy and Materials, Conference Proceedings

[43] A C H Pinha and J K Sagawa 2020 A system dynamics modelling approach for municipal solid waste management and financial analysis Journal of Cleaner Production 269

[44] C Frazzoli, O E Orisakwe, R Dragone and A Mantovani 2010 Diagnostic health risk assessment of electronic waste on the general population in developing countries’ scenarios Environmental Impact Assessment Review 30 (6)

[45] M K M Nasution 2018 No research without publication: Early mining Journal of Physics: Conference Series 978 (1)

[46] M K M Nasution, R Sitepu, Rosmanyati, D Bakti and S M Hardi 2018 Research mapping in North Sumatra based on Scopus IOP Conference Series: Materials Science and Engineering 309 (1)

[47] V Ahrens 2012 Inflation of industrial revolution [Inflation industrieller revolutionen] Productivity Management 17 (5)

[48] W Leonardus, M Wasono, F Alamsjah, Eldijena and Sasmoko 2018 Digital transformation in the age of industry 4.0: Acceleration of transformational performance through business model innovation and co-creation strategy in indonesian ict firms [Transformacin digital en la era de la industria 4.0: aceleracin del rendimiento de transformacin a travs de la estrategia de innovacin y co-creacin de modelos de negocios en empresas de tic de indonesia] Opcion 34 (86)

[49] A Setiawan, D Angela and B Irawan 2018 Modelling of Cutting Tool Condition Monitoring System (CTCMS) to support industry 4.0 MATEC Web of Conferences

[50] L W W Mihardjo, S Sasmoko, F Alamsjah and E Eldijena 2019 Digital leadership role in developing business model innovation and customer experience orientation in industry 4.0 Management Science Letters 9 (11)

[51] Iswanto 2019 Management information system based leadership to improve higher education in industry 4.0 International Journal of Recent Technology and Engineering 8(1)

[52] I Suryadi, H Ishak and Darmawansyah 2019 Spatial and Temporal Distribution and Environmental Factors Related to Larval Density An. Barbirostris and An. Subpictus in Bulukumba: An Approach to Industry 4.0 E3S Web of Conferences

[53] W K Sari and I Wilujeng 2020 Education change in the industry 4.0: Candidate science teacher perspective Journal of Physics: Conference Series 1440 (1)

[54] R N Hafni, T Herman, E Nurlaelah and L Mustikasari 2020 The importance of science, technology, engineering, and mathematics (STEM) education to enhance students’ critical thinking skill in facing the industry 4.0 Journal of Physics: Conference Series 1521 (4)

[55] K Mubarok 2020 Redefining Industry 4.0 and Its Enabling Technologies Journal of Physics: Conference Series 1569 (3)
[56] M K M Nasution, Onrizal and I Aulia 2019 Design of the research problem statement Journal of Physics: Conference Series 1235 (1)

[57] A Hidayatno, A R Destyanto and C A Hulu 2019 Industry 4.0 technology implementation impact to industrial sustainable energy in Indonesia: A model conceptualization Energy Procedia 156

[58] R S Dewi, T Alhabsi, Z Arifin and Y Abdillah 2020 Adaptive capability: Capability to create innovation and competitive advantages of SME’s in the industry 4.0 era International Journal of Innovation, Creativity and Change 11 (2)

[59] A H Sutawijaya and L C Nawangsari 2020 What is the impact of industry 4.0 to green supply chain Journal of Environmental Treatment Techniques 8 (1)

[60] E N Yunus 2020 The mark of industry 4.0: how managers respond to key revolutionary changes International Journal of Productivity and Performance Management

[61] A Wijaya and H O Sinaga 2019 Empowering traditional farmers in escalating farming towards Industry 4.0-ready International Journal of Innovation, Creativity and Change 6 (6)

[62] M Lubis, L Arif Ridho, B Lubis and A Lubis 2018 Incremental Innovation towards Business Performance: Data Management Challenges in Healthcare Industry in Indonesia MATEC Web of Conferences 218

[63] Q C Kainde and J R Batmetan 2019 Digital business model for digital startup in industrial era 4.0 International Journal of Advanced Trends in Computer Science and Engineering 8

[64] M L Singgih, Y Prasetyawan, Sutikno, D Hartanto, F R Kurniawan and W T Wicaksana 2019 Maintenance management improvement based on reliability centered maintenance II in energy generating industries IOP Conference Series: Materials Science and Engineering 528 (1)

[65] N T Putri, D Jumeno, Henmaidi, E Wirdianto, P Fithri and F Zulkhaira 2019 Designing Self-Assessment Tool for Library Performance Measurement Adopting Malcolm Baldrige Framework (Case Study: Central Library of Andalas University) IOP Conference Series: Materials Science and Engineering 528 (1)

[66] H Indrawan, N Cahyo, A Simaremare, S Aisyah, P Paryanto and P Munyensanga 2019 A developed analysis models for industry 4.0 toward smart power plant system process 2019 International Conference on Information and Communications Technology, ICOIACT 2019

[67] I Kambarov, G DAntonio, K Aliev, P Chiabert and J Inoyatkhodjaev 2018 Uzbekistan towards industry 4.0. defining the gaps between current manufacturing systems and industry 4.0 IFIP Advances in Information and Communication Technology 540

[68] C S Quevedo, C C Sanchez, W A Diaz and J E R Polo 2018 Productivity improvement for the manufacture of disposable medical material in a South American Country pointing towards industry 4.0. Proceedings of the LACCEI international Multi-conference for Engineering, Education and Technology

[69] M Chuks and T Arnesh 2019 Implications of industry 4.0 in Nigeria electoral system Proceedings of the International Conference on Industrial Engineering and Operations Management

[70] W Maisiri and L van Dyk 2019 Industry 4.0 readiness assessment for South African industries South African Journal of Industrial Engineering 30 (3)

[71] A Ahadov, E S Asgarov and I El-Thalji 2019 A summary of adapting Industry 4.0 vision into engineering education in Azerbaijan IOP Conference Series: Materials Science and Engineering 700 (1)

[72] R A Kamaev, Y U A Levin and M A Sokolnikov 2019 Formation of technological structures in the textile industry: Production and regional aspects Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Tekhnologiya Tekstil'noi Promyshlennosti, Volume 2019-January, Issue 1

[73] O Bongomin, E O Nganyi, M R Abswaidi, E Hitiyise and G Tumusiime 2020 Sustainable and Dynamic Competitiveness towards Technological Leadership of Industry 4.0: Implications for
East African Community Journal of Engineering (United Kingdom) 2020

[74] A Iyer 2018 Moving from Industry 2.0 to Industry 4.0: A case study from India on leapfrogging in smart manufacturing Procedia Manufacturing 21

[75] Y Yin, K E Stecke and D Li 2018 The evolution of production systems from Industry 2.0 through Industry 4.0 International Journal of Production Research 56 (1-2)

[76] D A Zakoldaev, A V Shukalov, I O Zharinov and O O Zharinov 2019 Modernization stages of the Industry 3.0 company and projection route for the Industry 4.0 virtual factory IOP Conference Series: Materials Science and Engineering 537 (3)

[77] D A Zakoldaev, A V Shukalov, I O Zharinov and O O Zharinov 2019 Realization of project procedures in the item designing companies of the Industry 3.0 and Industry 4.0 Journal of Physics: Conference Series 1333 (7)

[78] D A Zakoldaev, A G Korobeynikov, A V Shukalov, I O Zharinov and O O Zharinov 2019 IOP Conference Series: Materials Science and Engineering 734 (1)

[79] M K M Nasution 2020 Without research, no community service Journal of Physics: Conference Series 1542 (1)

[80] M K M Nasution 2020 Research serendipity: A challenge for changing Journal of Physics: Conference Series 1542 (1)