An Overview of Industry 4.0: Definition, Components, and Government Initiatives

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Shu Ing Tay
Universiti Tun Hussein Onn Malaysia

Lee Te Chuan
Universiti Tun Hussein Onn Malaysia

A. H. Nor Aziati
Universiti Tun Hussein Onn Malaysia

Ahmad Nur Aizat Ahmad
Universiti Tun Hussein Onn Malaysia

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S.I. Tay, Department of Production and Operation Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, Batu Pahat, Johor, Malaysia. E-mail: hp170077@siswa.uthm.edu.my

T.C. Lee, Department of Production and Operation Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, Batu Pahat, Johor, Malaysia. E-mail: tclee@uthm.edu.my*

N.A. A. Hamid, Department of Production and Operation Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, Batu Pahat, Johor, Malaysia. E-mail: aziati@uthm.edu.my

A.N.A. Ahmad, Department of Production and Operation Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, Batu Pahat, Johor, Malaysia. E-mail: aizat@uthm.edu.my

Abstract--- The term "Industry 4.0" was initially coined by the German government which describes and encapsulates a set of technological changes in manufacturing and sets out priorities of a coherent policy framework with the purpose of maintaining the global competitiveness of German industry. Industry 4.0 has brought many professions to change. People are 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. In this paper, the general definition of Industry 4.0 will be discussed. Generally, Industry 4.0 refers to the means of automation and data exchange in manufacturing technologies including Cyber-Physical Systems, Internet of Things, big data and analytics, augmented reality, additive manufacturing, simulation, horizontal and vertical system integration, autonomous robots as well as cloud computing. It serves a role to help integrate and combine the intelligent machines, human actors, physical objects, manufacturing lines and processes across organizational stages to build new types of technical data, systematic and high agility value chains. All these components will also be discussed in this paper. Additionally, government initiatives by various countries toward Industry 4.0 will also be presented in this paper.

I. Introduction Industry 4.0

Before Industry 4.0, 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.

Industry 1.0 began around the 1780s with the introduction of water and steam power which helped in mechanical production and improved the agriculture sector greatly. Next, Industry 2.0 is defined as the period when mass production was introduced as the primary means to production, in general. The mass production of steel helped introduce railways into the industrial system which consequently contributed to mass production at large.

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 (Liao et al., 2017).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 (Gorecky et al., 2014).

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. Big international companies that use concepts of continuous improvement and have high standards for research and development will accept the concept of Industry 4.0 and make themselves even more competitive in the market (Marcos et al., 2017).

This becomes possible by introducing self-optimization, self-cognition, and self-customization into the industry. The manufacturers will be able to communicate with computers rather than operate them. The schematic diagram of overview for the industrial revolutions is illustrated in Figure 1.

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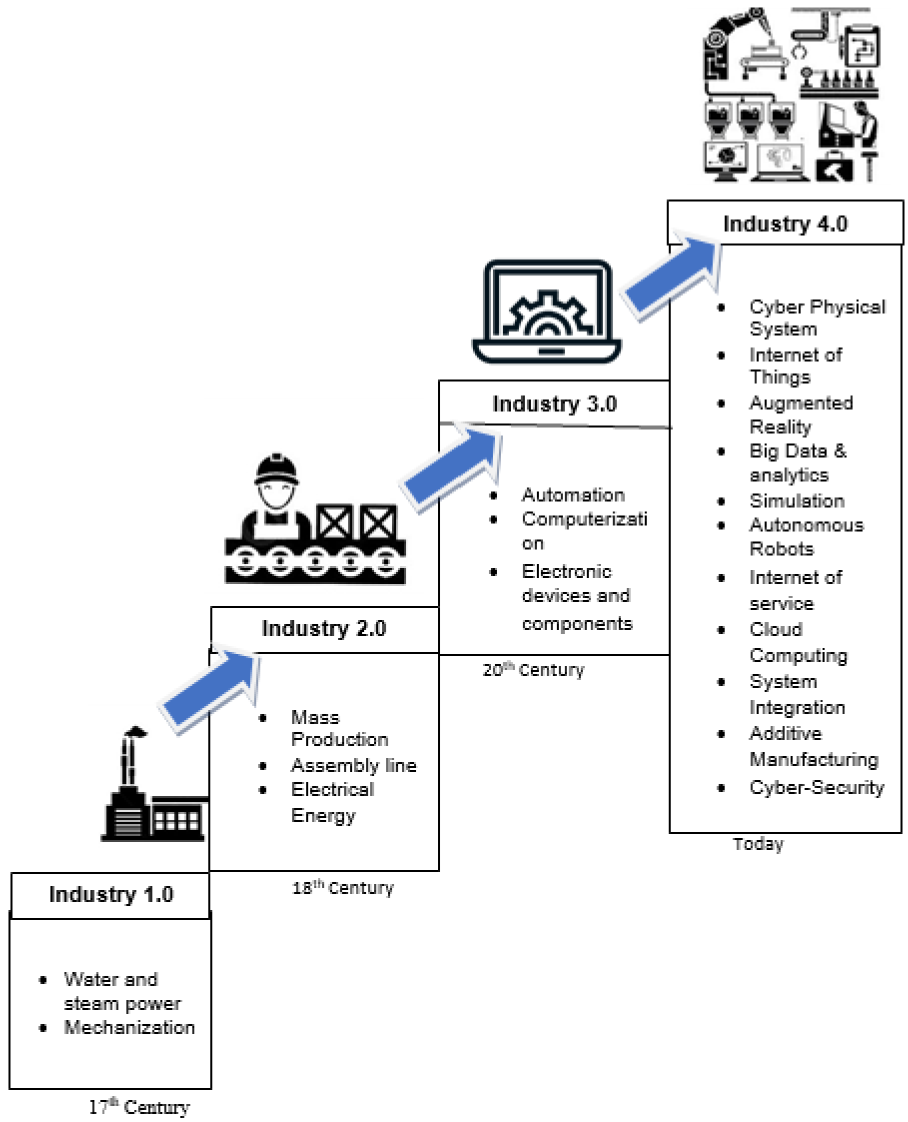

Figure 1: The Industrial Revolution

II. 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(Mrugalka & Wyrwicka, 2017). 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 (Qin, Liu &Grosvenor, 2016). 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.

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Table 1: Summary of Definition of Industry 4.0

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.
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).
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 concept in the development of global industry and the world economy.
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.
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 table above, 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. Besides that, some of the authors concentrated Industry 4.0 on the cost factor and profitability with recently developed high-tech information and intelligent services. From previous research on Industry 4.0,in the beginning the focus was mostly on the sector of industrial manufacturing 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 goods 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 describes a future scenario of industrial production that is characterized by new levels of controlling, organizing and transforming the entire value chain with the life cycle of products,resulting in higher productivity and flexibility through three types of effective integration which are horizontal, vertical and end-to-end engineering integration. Hence, these can predict product performance degradation and autonomously manage 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 requirements and are parts of the visionary concept of Industry 4.0.

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III. Components of Industry 4.0

Industry 4.0 can be classified into three components. The first is horizontal integration. It brings the concept of a new type of worldwide value chain networks. The second is vertical integration. The concept is to achieve hierarchical subsystems at the production line to produce an easy to configure and high flexibility production line. The last component is engineering integration along the whole value chain from the beginning to the end to assist in the customization of products. The horizontal integration is described as one where a corporation should both cooperate and compete with corporations that have similar characteristics to create an efficient production system. Material, financial control and knowledge can be connected in all these companies easily. Therefore, new control systems and models for business may appear (Wang et al., 2016). Vertical integration delivers the idea of a factory that has various informational and physical subsystems, for example like production management, actuator and sensor, value and corporate planning. It is important for the vertical integration of sensor and actuator signals along various stages of the enterprise resource planning (ERP) level to ensure high flexibility and ease to configure production lines. From this integration, the highly intelligent machines create an automated controlled system that is able to be automatically reconfigured according to the various types of products. The large amounts of data collected and processed enables the manufacturing system to be transparent(Wang et al., 2016). Lastly, End-To-End engineering integration in a chain of activities throughout the product-centric value creation process involves aspects such as customer requirement expression, product development and design, recycling, production engineering, production services, production planning and maintenance. From end-to-end integration, every stage can be reused for the same product model. Product design effects on services and production can be predicted by utilizing a software tool in the chain to make sure the products are customizable (Wang et al., 2016).

IV. Characteristics of Industry 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 characteristics for industry as shown in Figure 2 below.

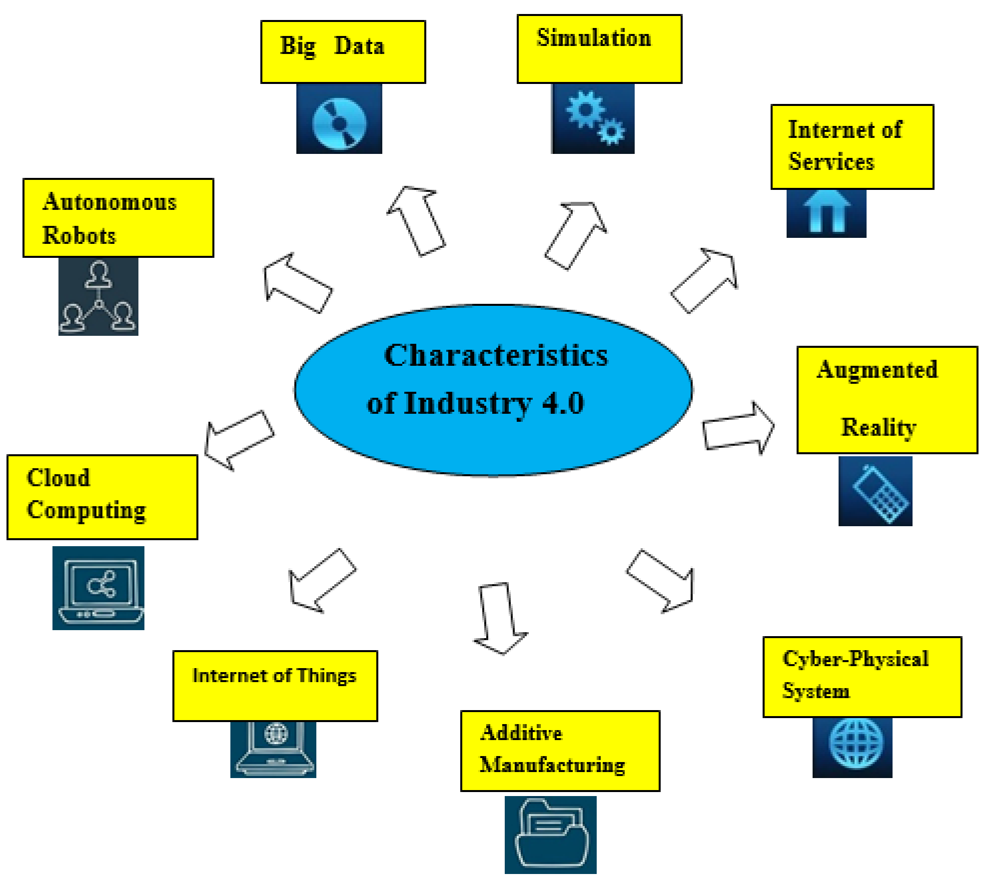

Figure 2: Characteristics of Industry 4.0.

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Cyber-Physical System (CPS)

Industry 4.0 can be played as a Cyber-Physical System study where the advances and speed of development in communication and calculation form the Cyber-Physical System and Industry 4.0. Each production 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) (Mosterman & Zender, 2015).CPS 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(He, 2016).

Internet of Things (IoT)

Industry 4.0 is the new phrase 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 (Kagermann, Wahlster & Johannes (2013). Generally, IoT can provide 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 (Zhong et al., 2017).

Internet of Services (IoS)

Internet of Services acts as important components in the automotive industry. Activities are triggered through data transfers in the information technology to make daily mobility safer, easier and pleasant. The Internet of Services (IoS) acts as “service vendors” to provide services through the internet according to the types of digitalization services. These services are available and on demand around business models, partners and any setup for services. The suppliers provide and aggregate the services into additional value services as communication among consumers can be received and accessed by them through various channels(Buxmann, Hess, & Ruggaber, 2009).

Big Data and Analytics

Under Industry 4.0, big data analytics is beneficial for predictive manufacturing and is an important direction for industrial technology development through the rapid development of the Internet. This leads to huge amounts of information produced and obtained daily where current processing and analysis is unable to cope using traditional methods. Hence, big data has become a hot topic recently in Industry 4.0. Many 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(Witkowski, 2017).

Augmented Reality

Augmented Reality (AR) has begun to be considered as one of the most promising business that technological companies should heavily invest in. This technology 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(Masoni et al., 2017).

Autonomous Robots

Current robots have higher flexibility, advanced functions and are easier to operate in multitudes of fields. In the near 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.

Additive Manufacturing (3D Printing)

Industry 4.0 is stimulating the utilization of advanced data technologies and smart production systems. Hence, additive manufacturing is one of the crucial tools to embrace Industry 4.0. The implementation of new manufacturing skills for the purpose of integrating information technologies plays a crucial role in the competitiveness of the economy. The advancement of cyber technology has encouraged the transition to Industry 4.0. The trend of looking for new materials available using additive manufacturing is increasing. Certain required

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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 (Dilberoglu et al,. 2017).

h) Cloud Computing (CM)

Cloud computing is a relatively new system logic that provides a huge space of storage for the user. A small amount of money allows enterprises or individuals to access these resources. Over 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. Company limitations can be minimized since more data sharing will occur across sites for production-related undertakings in the industrial revolution. Cloud computing is slowly becoming a consideration 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 (Xu, 2012).

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 done 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. Latest 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 (Rodič, 2017).

V. Government Initiatives

Industry 4.0 is defined as an amalgamation of advanced technologies where the internet is extensively used to support certain technologies such as embedded systems. It serves a role to integrate and combine the intelligent machines, human actors, physical objects, manufacturing lines and processes across organizational stages, building new types of technical data, systematic systems and high agility value chains (Schumacher, Erol & Sihn, 2016).Germany launched the strategic initiative mooted in 2011 under its High-Tech Strategy 2020 with the purpose to switch from centralized to decentralized networks which connect devices and equipments that communicate with each other and able to respond accordingly to gain information for revolutionizing the manufacturing industry(Wang et al., 2016). Kagermann, Wahlster & Johannes in 2013 had published the main ideas of the fourth industrial revolution to construct the base for the Industry 4.0 manifesto. The study was published by the German National Academy of Science and Engineering in 2013. The Public Private Partnership (PPP) for Factories of the Future (FoF) deployed and initiated discussions on related topics of Industry 4.0 at the European level. In the United States of America, the Industrial Internet Consortium (ICC)promoted Industry 4.0 (Liao et al., 2017). This new industrial revolution provides scope for many of the basic ideas that had been widely implemented in many other countries. Internationally, many governments have realized the trend and have taken action to react specifically to the impact Industry 4.0 would bring to the manufacturing industry. Some of the governments' plans are as stated below:

(a) In 2011, to make sure the United States of America (USA) will be well prepared for the next generation of manufacturing revolution, USA President Barack Obama started a series of national-level actions, discussions and recommendations, titled 'Advanced Manufacturing Partnership (AMP)', (President's Council of Advisors on Science and Technology, 2014). AMP was an initiative undertaken to make more USA companies ready to invest heavily in advanced technology. In 2017, the global programmable logic controller market was estimated at USD 8.491 billion and is expected to achieve USD 10.595 billion by 2023, registering a CAGR of 3.7% during 2018-2023 (the forecast period).

(b) In 2012, an action plan known as 'High-Tech Strategy 2020' was passed by the German government. This project grants billions of Euros each year to develop the latest technologies in the manufacturing industry (Liao et al., 2017). In 2018, Volkswagen introduced the 48V progressive hybrid, VTG turbocharger and Miller combustion process and mild hybrid diesel systems for its new vehicles.

(c) In 2013, the French government launched 'La Nouvelle France Industrielle'. This program prioritized 34 sector-based ways in France's industrial policy (Conseil national de l'industrie 2013). French start-up 2B1st Consulting introduced at Hannover Messe a collaborative digital tool designed to help companies implement Industry 4.0 solutions.

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(d) In 2013, a long term action plan for the manufacturing industry in the United Kingdom (UK) called the 'Future of Manufacturing' was implemented. This program refocused and rebalanced the policies to support the resilience of UK manufacturing until 2050(Foresight, 2013). In 2018, Rolls-Royce is partnering with the Alan Turing Institute to explore how Artificial Intelligence (AI) and analytics can be applied at scale to supply chains and predictive maintenance regimes.

(e) In 'Factories of the Future (FoF)'in 2014, the European Commission adopted a new contractual Public-Private Partnership (PPP). A total of almost 80 billion Euros of funding for the consecutive 7 years in the period of 2014 to 2020 will be provided for the program Horizon 2020(European Factories of the Future Research Association, 2016). In 2018, the European Commission announced a new series of measures to put artificial intelligence (AI) at the service of citizens and boost Europe's competitiveness in the field with a budget of €20 billion by the end of 2020.

(f) 'Innovation in Manufacturing 3.0', a plan launched by the South Koreans in 2014 had emphasized four ways and tasks for improvement of Korean manufacturing (Ministry of Trade Industry and Energy of South Korea, 2014). As a result, Hyundai developed a new autonomous car, the Hyundai Genesis sedan, which is capable of tracking moving objects, avoiding collisions, driving on narrow roads and recognizing traffic lights and speed limit signs.

(g) In 2015, China's government launched two actions simultaneously i.e. the 'Internet Plus' and 'Made in China 2025' strategies. Ten major aspects in the sector of manufacturing are prioritized to boost the industrialization of China (China State Council, 2015). In 2018, the Chinese government announced elimination of rules that required car manufacturers such as General Motors to collaborate with a local company to open factories in China. China anticipates the move will encourage foreign companies to bing more advanced technology into China to meet demands for electric transportation.

(h) In 2016, the Singapore government launched its RIE 2020 Plan (Research, Innovation and Enterprise) with a budget of $19 billion. The advanced manufacturing and engineering domain had identified eight key vertical industries for the Plan (National Research Foundation 2016).In 2018, Singaporean companies are developing machines that can help make slight tweaks to fully automate hydroponic farms and maximize crop yield.

(i) In Malaysia, the government aggressively took action by undertaking various efforts in helping industry players to embrace Industry 4.0 through the implementation of automation and smart manufacturing. In Budget 2017, the government highlighted several new incentive packages to accelerate the growth and adoption of manufacturing and Industry 4.0 in Malaysia. For instance, Supermax Corporation Bhd. was a glove manufacturing industry which under the automation and Industry 4.0 in manufacturing will be supported by the government through incentive programmes to spur the growth of the industry. Former Prime Minister of Malaysia, Datuk Seri Najib Razak initiated the government's plan to implement TVET in industries. This is to assist the development of Industry 4.0 in the future by increasing the capabilities of the workforce. Under this program, the government allocated RM50 million to improve the caliber and the competitiveness of the workforce to help in the economic development of the nation. This budget is allocated from 30% of the Human Resources Development Fund (HRDF) funds specifically for the purpose of TVET.

In short, the government's plans above show that developing countries are significantly focused on the advancement of technologies and the fact that industry 4.0 can bring many positive impacts to a nation's development. As the physical world, biological world and digital world keep on converging, advanced technologies and phases will provide opportunities for citizens to interact with their government and voice their opinions and even circumvent the supervision of oppressive public authorities.

VI. Conclusion

In a nutshell, Industry 4.0 is the future of global manufacturing which aggregates existing ideas to a new value chain which plays a crucial role to transform whole value chains of life cycle of goods while developing innovative services and products in the manufacturing industry which involves the connection of systems to things that creates self-organizing and dynamic control within an organization. Industry 4.0 describes a future scenario of industrial production that is characterized by the aspects of a new level of controlling, organizing and transforming the entire value chain with the life cycle of products,resulting in higher productivity and flexibility through three types of effective integration which are horizontal, vertical and end-to-end engineering integration. Hence, these can predict product performance degradation and autonomously manage and optimize product service needs and consumption of resources which lead to optimization and reduction of costs. Next, the creation of dynamic, real-time optimized and self-organizing cross-company value networks through the Cyber-Physical Systems(CPS), Internet of Things

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(IoT), artificial intelligence (AI), additive manufacturing, cloud computing and others are added. It is hoped that with the proper guidance and technical skills, more and more manufacturing companies in Malaysia will implement Industry 4.0 in their business.

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