Industry 4.0 And It Effects Toward Industry

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Abstract

Many of the world's leading industrial nations have invested in national initiatives to foster advanced manufacturing, innovation, and design for the globalized world. Much of this investment has been driven by visions such as Industry 4.0, striving to achieve a future where intelligent factories and smart manufacturing are the norm. In this paper will discuss on definition of industry 4.0 and the distribution of the manufacturing system attribute for the Industry 4.0. Manufacturing system attributes to the Industry 4.0 can be said as nine advances in technology. From Economic Planning Unit (2015) in Eleventh Malaysia Plan, which is a five-year comprehensive blueprint prepared by the Economic Planning Unit (EPU) of Malaysia, the government aims to raise productivity and reduce dependency on inputs from capital and labour. The conceptual Industry 4.0 has a high impact and wide range of change to manufacturing processes, outcomes and business models. It allows mass customization, increase of productivity, flexibility and speed of production and improvement on quality product. Although Industry 4.0 have several disadvantages, some of its can be minimize and can be prevent. The ideas to minimize the disadvantages are predictive maintenance, upgrade the security data, and smart monitoring.

Keywords: Intelligent factories, Smart manufacturing

1. What is the industry 4.0?

Industry 4.0 is a vision of smart factories built with intelligent cyber-physical systems as stated by Thames and Schaefer (2016). Meanwhile, Calero Valdez et al. (2015) clearly state that Industry 4.0 is describes a paradigm shift in production technology. But, Lu (2017) states there is no unanimously adopted definition of Industry 4.0 through his study which summarized 18 numbers of publications since 2011 to 2016. Previously, Industry 4.0 was launched by Germany as a strategic initiative to take up a pioneering role in industrial IT which is currently revolutionizing the manufacturing engineering sector. According to Qin, Liu and Grosvenor (2016), Germany provides a Research and Development funds to industrial development by hoping the industrial technology to grow rapidly.

Today, Industry 4.0 can be said that it is the ending point for traditional centralized application of production control. This is due to the advances in digitalisation and the internet, “smart manufacturing” and “smart factories” are becoming a reality, where the manufacturing value chain in the physical world can be integrated with its virtual copy in the cyberspace through Cyber-Physical Systems (CPS) and Internet of Things (IoT), and then be seamlessly integrated with Internet of Services (IoS). That advancement, which is known as Industry 4.0, was proposed and launched in 2013 required 10-20 years in practice for achieving full capability to organize production in conformity with the Industry 4.0 concept, especially by the small and medium-sized enterprises (SMEs) as stated by Zawadzki and Zywicki (2016).

Cyber-physical systems (CPS) are enabling technologies which bring the virtual and physical worlds together to create a truly networked world in which intelligent objects communicate and interact with each other. The deployment of CPS in production system creates what has been called a "smart factory". Within the modular structured smart factories, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and with humans in real time, and via the IoS, both internal and cross-organizational services are offered and used by participants of the value chain.

Smart factory products, resources and processes are characterized by CPS that can provide significant real-time quality, time, resources, and cost advantages in comparison compared to the traditional production systems. According to Zawadzki and Zywicki (2016), they state that in future, companies that implement the concept of a smart factory will become leaders in the manufacturing field. In addition, according to Thames and Schaefer (2016), the goal of Industry 4.0 is to achieve a higher level of operational efficiency and productivity, as a higher level of automatization. Figure 1 shows the requirement and necessary elements needed in order to achieve the mass customization through industry 4.0 which is also known as smart factory Zawadzki and Zywicki (2016).

Saldivar et al. (2015) conclude the design principles of industry 4.0 components are as shown in Table 1. It is clearly shown that, smart factory is the most significant components in industry 4.0 due to the four design principles.

2. What will be the manufacturing system attribute for the industry 4.0?

Manufacturing system attributes to the Industry 4.0 can be said as nine advances in technology as stated in the study of Rüßmann et al. (2015). Many of the attributes are already been used in the manufacturing system and are simplified in the Table 2. Correspondingly, it can be said that one of the most important characteristic of the manufacturing system in Industry 4.0 are autonomous and well-driven. This is support by Lee, Bagheri and Kao (2015) study that categorized the three components of Industry 4.0 in Table 3 which clearly pointed out the attributes and technologies differentiation between the current factory manufacturing and Industry 4.0 manufacturing system.

The traditional production line aims to produce the single type of products meanwhile the smart factory production system aims to process multiple types of products. This statement is agreed by Wang et al. (2016) that clearly outline the differences of key features for the smart factory and traditional factory. From Table 4, it is also shown the features of Industry 4.0 production system are consist of six components which can also be defines as the characteristics of Industry 4.0.

3. What are the current stages of Malaysia Industries?

From Economic Planning Unit (2015) in Eleventh Malaysia Plan, which is a five-year comprehensive blueprint, the government aims to raise productivity and reduce dependency on inputs from capital and labour. One of the important solutions is to raise industrial productivity, where there will be greater adoption of automation and upgrading of skills. The role of industrial associations will also be further strengthened to deal with global competition through smart partnerships with other industrial associations in target export markets.

Automation and robotic industry in Malaysia has been implemented since 1983 by ex-prime minister Tun Dato' Seri Dr Mahathir bin Mohamad when he introduced the national car manufacturer, Proton, that was first established as the sole national car company until the advent of Perodua in 1993 . Despite the long involvement of automation and robotic in manufacturing, the idea of Industry 4.0 in Malaysia is mostly influenced by foreign companies such as KUKA and ABB. Very large manufacturing companies and multinational groups already consider this topic as very important. Small and medium enterprises (SME) do not yet appear to consider industry 4.0 to be of great relevance to them, although these companies are most likely to be the big winners from the shift. SME companies are often able to implement the digital transformation more rapidly because they can develop and implement new IT structure from scratch more easily. Very large manufacturing companies and

multinational groups, by contrast, have more complexity to deal with in terms of their existing, organically grown structures as stated by Bahrin et al. (2016).
Malaysian government agencies have come up with several initiatives to encourage the adoption of latest technology to local industry. The Malaysian Industry-Government Group for High Technology (MIGHT) is introduced to address the country's needs in response to the effects of globalization and trade liberalization on future economic growth through the accelerated use of high technology. Under this initiative, programs and activities will include building strategic partnerships and alliances, technology acquisition and nurturing, capacity building as well as strengthening the growth of these sectors through policy interventions and flagship programs. Malaysia aims to be at the forefront of the next generation of advances in science and technology through the newly set-up Global Malaysia-Korea Robotics Collaboration and Development Program where both parties have agreed to exchange robot human capital development programs, to undertake robot standardization cooperation, to launch robot exhibition and international cooperation as stated in press release (2014). MIMOS, which is Malaysia's national R&D center in ICT, are doing collaboration with China on research and development on smart manufacturing technology Laurence Sebastian (2015).
Therefore, the development of automation and robotic industry has the potential to lead Malaysia towards industry 4.0 through key initiatives by government and industry player alike.

4. What will be the positive and negative impact of Industry 4.0 to Malaysia?

The conceptual Industry 4.0 has a high impact and wide range of change to manufacturing processes, outcomes and business models. It allows mass customization, increase of productivity, flexibility and speed of production and improvement on quality product.

4.1 Positive impact

This mass customization will allow the production of small lots even as small as single unique items due to the ability of rapidly configure machines to adapt to customer-supplied specifications and additive manufacturing. This flexibility also encourages innovation, since prototypes or new products can be produced quickly without complicated re- tooling or setup of new production lines. Thus it can produce one product and many variants, with a decrease in inventory by using Industry 4.0 technologies as stated by Schmidt and Möhring (2015). Gruber (2013) stated that the speed with which a product can be produced also improved where digital designs and virtual modelling of manufacturing process reduce the time between the design of a product and its delivery. In Germany, data-driven supply chains can speed up the manufacturing process by an estimated 120% in terms of time needed to deliver orders and by 70% for the time to get products to market.
Integrating product development with digital and physical production has been associated with large improvements in product quality and

significantly reduced error rates. Data from sensors can be used to monitor every piece produced rather than using sampling to detect errors, and error-correcting machinery can adjust production processes in real time. This data can also be collected and analyzed using 'big data' techniques to identify and solve small ongoing problems. The rise in quality plays an important role in reducing costs and hence increasing competitiveness as stated by Bahrin et al. (2016). According to Sommer (2015), the top 100 European manufacturers could save the costs of scrapping or reworking defective products if they could eliminate all defects.

Productivity can also increase through various Industry 4.0 effects. By using advanced analytics in predictive maintenance programs, manufacturing companies can avoid machine failures on the factory floor and results in downtime cut and increase production as stated by Almada-Lobo (2016). Some companies will be able to set up 'lights out' factories where automated robots continue production without light or heat after the staff has gone home. Human workers can be used more effectively, for those tasks which are really important.

4.2 Negative impact

It is very important to recognize and evaluate the economic effects of Industry 4.0, the digitalization of the production processes. These developments involve considerable challenges at the enterprise and at the political level. Challenges which have been identified include Mosterman and Zander (2016). The consequences by implementing Industry 4.0 as stated:

i. IT security issues.
ii. Reliability and stability needed for critical machine-to-machine communication (M2M), including very short and stable latency.
iii. Need to maintain the integrity of production processes need to avoid any IT snags, as those would cause expensive production outages.
iv. Need to protect industrial knowhow (contained also in the control files for industrial automation gear).
v. Lack of adequate skill-sets to expedite the march toward the fourth industrial revolution.
vi. Threat of redundancy of the corporate IT department General reluctance to change by stakeholders.
vii. Loss of many jobs to automatic processes and IT-controlled processes, especially for lower educated parts of society

Perhaps the most challenging aspect of implementing Industry 4.0 is the IT security risk. Industry 4.0 will require on-line integration among several entities, and this online integration will give room to security breaches and data leaks. Cyber theft would be another dangerous threat. In this case, the problem is not individual, and this will cost manufacturers substantially and might even hurt their reputation. Therefore, security is a crucial issue that should be dealt with seriously.

The transformation to Industry 4.0 will require large investments in new technology, and the decision for such transformations will have to be taken at the CEO level. Even then, the risks must be calculated and taken seriously. While it is still early to speculate on employment issues with the advent of Industry 4.0, it is safe to accept that workers will need to acquire different or an all-new set of skills. As stated by Tupa, Simota and Steiner (2017). This may help employment rates go up, but it will also alienate a big sector of workers. The sector of workers whose work is perhaps repetitive and routine will face a stiff challenge to keep their jobs. New and quite different educational systems must be introduced, but this still does not solve the problem for older workers. This is an issue that might take quite a long time to solve.
The last impact is privacy is not only the customer's concern, but also the manufacturers as stated by Mosterman and Zander (2016). In such an interconnected Industry 4.0 network, manufacturers need to collect and analyze a huge quantity of data. To the customers, this might look like a threat to their privacy. Narrowing the gap between the consumer and the manufacturer will be a huge challenge for both parties.

4.3 Critical Thinking

The Fourth Industrial Revolution has been talking a lot nowadays. New technologies are appearing every day. Only think of artificial intelligence, 3D printing, Big Data, augmented reality, nanotechnology, autonomous transport, Internet of Things, machine learning and robotics. These were the implication of the Fourth Industrial Revolution.

4.3.1 Manufacturing jobs change

As the world going to technologies, the manufacturing industry also has changing and it is changing quickly. Dirty and simple jobs in factories disappear, while new positions seem to pop-up every day. As the industry revolved into automated system, the need of a maintainer is become necessary as also as programmer that is highly needed in Fourth Industrial Revolution. Nanotechnology and artificial intelligence have to be explored further to be used in manufacturing; means that more researchers is needed. As for that, one thing is clear; manufacturing jobs are definitely changing.

4.3.2 Skills

As the industry is changing rapidly, we need to change fast as well. Continuously learning and gaining new knowledge is necessary for a career in manufacturing. Also, complex problem solving, critical thinking and creativity are three of the most important skills in Fourth Industrial Revolution. These important skills are necessarily to be taught at institution. To prepare students and adolescents for a job in manufacturing or in any branches and needed to focus on ‘learning to learn’, next to addressing new skills. In this way youngsters will be able to occupy jobs that do not exist yet.

4.3.3 Different strategy for manufacturer

As the manufacturing industry changes, the way companies produce is changing too. Whereas offshoring has been a good strategy for decades, new technologies make it more attractive to reshore production. Reshoring is just one strategy that manufacturers can follow to keep up with Industry 4.0.
In addition, hiring women and encouraging them to take a job in manufacturing, is a good strategy. Integrating Information Technology and increasing the cooperation between IT and Operation Technology, will help the supply chain to gain value. Using the power of Big Data is also a strategy that helps to become ready for the future of manufacturing. These are only a few strategies that manufacturers can adapt to remain competitive.

4.3.4 Information technology
Network readiness is one of the important pillars of future competitiveness and well-being in manufacturing. As innovation is increasingly based on digital technologies, new business models need to be developed. Network readiness, as stated in The Network Readiness Index 2016, refers to overall environment, readiness in terms of infrastructure, affordability and skills, and usage by individuals, businesses and the government. In order to become ready for the future of manufacturing, countries should consider all these factors and improve on them where necessary.

5. How disadvantage can be minimizing?

Although Industry 4.0 have several disadvantages, some of its can be minimize and bee prevent. The ideas to minimize the disadvantages are predictive maintenance, upgrade the security data, and smart monitoring.

5.1 Predictive Maintenance
Predictive Maintenance describes foresighted maintenance of a production process with the help of intelligent data analytics. Machines, products and components of the systems involved in the process are cross-linked. The goal is to detect suspicious patterns indicating malfunction early enough to initiate the appropriate preventive measures. Impending errors, breakdowns and resulting downtimes in the production process can thus be detected in time and the appropriate maintenance can be initiated.
Predictive Maintenance is an important component in a 4.0 environment and is a further development of established maintenance strategies. With the right choice of systems, the generation and preparation of the correct data, as an appropriate mix of industry expertise and data analytics, the success of a Predictive Maintenance solution is guaranteed.

5.2 Upgrade the Security Data
Every day, business systems generate huge amounts of data, which, hover, is only in part processed and analysed. In the field of security, it is processed with software relating to the topic of SIEM (Security Information and Event Management). Conventional SIEM solutions are usually used for the analysis of log files. For this purpose, rules reacting

to known events are defined. Hover, by implication, this means that they cannot react early enough to undefined anomalies and events. SIEM systems are normally restricted to infrastructural events, and only provide limited support in making decisions.

5.3 Smart Monitoring

Constantly monitoring the IT environment with a Smart Monitoring solution allows an early detection of critical statuses in your server systems, services and their applications. The operation of complex IT infrastructures requires the employment of professional equipment and experts to supervise the systems. A malfunction of business-critical applications inevitably leads to economic losses. With the graphical user interface, events can be pursued, searched and filtered. Notifications can be transmitted in real-time via SMPT, SNMP, Syslog or HTTP POST. Admins have the possibility to filter the results according to event, date or IP address. Only data matching the admin's field of duty is displayed. Third-party companies can also send messages to SIEM tools.

5.4 A framework for Industry 4.0

In Industry 4.0 machines are starting to support humans to make decisions and do work in areas too hazardous, or with tasks too complex. Four ingredients combined bring Industry 4.0 that is instrumented, interconnected; inclusive and intelligent (refer Figure 2).

5.4.1 Instrumented

The devices carry around generate data; the cars that drive generate data. The exercise and sleep monitors generate data. More and more of the products and services interact with will be generating data. That's on top of the data generate ourselves with all our status updates, posts, videos, photos and more awash with it. It's getting quicker too. The speed with which the data gets from chips to analytics is accelerating as Texas Instruments and ARM have found working with IBM. All that data is no use unless it's moved somewhere it can be analysed. That could be where it originates, in a cloud, or both such as IBM's BlueMix – all that data needs somewhere secure to go.

5.4.2 Interconnected

Apple's latest OS updates included Siri, the interface you can talk to; Google's Home and Amazon's Echo all make it easier for us to talk to our connected devices and for them to do things– including answer back. There are clouds that hold our information and process it, and fog computing' that does what clouds do – but on the ground at the edge of the network' as IBM and Cisco do.

There are also platforms to help process the information, like the Watson IoT Platform. If you're familiar with 'The Hitch Hiker's Guide to the Galaxy's' 'Babel Fish' or Star Trek's 'Universal Translator', these platforms provide a place to receive the data, translate it into a common format that the computing 'brains' can work with, and pass back the results and insight.

Those standards are important too. With such a variety of development happening at speed, there’s always the chance of another ‘betamax’ or ‘VHS’ showdown. Companies need to agree and conform to standards such as ASPICE, ISO 26262 and many others to ensure that all continue to talk the same language.

5.4.3 Inclusive
Do you have an alarm that knows that the weather is going to be bad? That the bad weather will jam up the traffic. As a result of that jammed traffic, your journey take longer, so your alarm gets you up a little earlier so that you’re not late for work? This is an example of a three of data sets (weather, traffic and maps) that working together with a device (your alarm clock) can anticipate a need for you and change your environment to accommodate for it. Applying data from one place such as the weather Company to another can make a significant difference, and keep you on time for the office.

6. Conclusion
Currently, Industry 4.0 is a popular term to describe the imminent changes of the industry landscape, particularly in the production and manufacturing industry of the developed world. Yet the term is still used in different contexts and lacks an explicit definition. Especially for companies in the western automotive, machine and plant industry it will be important to offer customized products that are superior in quality and competitive in price. This can be achieved by intelligent automation and reorganization of labour within the production system. In the near future, labour work will change in content but will still remain irreplaceable, especially in view of customization resulting in an increasing need for coordination. Operators on the shop-floor need to be skilled in decision making as the separation of dispositive and executive work voids. Self-controlling systems communicate via the Internet and human, which alters the role of workers towards coordinators and problem-solvers in case of unforeseen events. But the main question were to be ask; is Malaysia industry were prepared to involved in Fourth Industrial Revolution. A big preparation and consequences needed to be considering has been discuss before.

REFERENCES

Almada-Lobo, F. (2016). Journal of Innovation Management, *‘The Industry 4.0 revolution and the future of Manufacturing Execution Systems (MES)’*, 3(4), 17.

Bahrin, M. A. K. et al. (2016). Jurnal Teknologi. *‘Industry 4.0: A review on industrial automation and robotic’*,78(6–13), 137–143.

Calero Valdez, A. et al. (2015). *'Reducing complexity with simplicity-usability methods for industry 4.0'*, Proceedings 19th Triennial Congress of the IEA, 9(August), 14.

Economic Planning Unit. (2015). Eleventh Malaysia Plan. Putrajaya: PNMB

Gruber, F. E. (2013). Digital Product and Process Development Systems. *'Industry 4.0: A Best Practice Project of the Automotive Industry'* ,411, 36–40.

Lee, J., Bagheri, B. and Kao, H. A. (2015). Manufacturing Letters. Society of Manufacturing Engineers (SME). *'A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems'*,3, 18–23.

Lu, Y. (2017). Journal of Industrial Information Integration. Elsevier Inc. *'Industry 4.0: A survey on technologies, applications and open research issues'*,6, 1–10.

Mosterman, P. J. and Zander, J. (2016). Software and Systems Modeling. Springer Berlin Heidelberg. *'Industry 4.0 as a Cyber-Physical System study'*, 15(1), 17–29.

Qin, J., Liu, Y. and Grosvenor, R. (2016). Procedia CIRP. The Author(s). *'A Categorical Framework of Manufacturing for Industry 4.0 and beyond'*,52, 173–178.

Rüßmann, M. et al. (2015). *'Industry 4.0. The Future of Productivity and Growth in Manufacturing'*, Boston Consulting, (April), 1–5.

Saldivar, A. A. F. et al. (2015). *'Industry 4.0 with cyber-physical integration: A design and manufacture perspective'*, 2015 21st International Conference on Automation and Computing: Automation, Computing and Manufacturing for New Economic Growth, ICAC 2015, (September), 11–12

Schmidt, R. and Möhring, M. (2015). *'Industry 4.0-Potentials for Creating Smart Products : Empirical Research Results'*, (June).

Thames, L. and Schaefer, D. (2016). Procedia CIRP. The Author(s). *'Software-defined Cloud Manufacturing for Industry 4.0'*,52, 12–17.

Tupa, J., Simota, J. and Steiner, F. (2017). 'Aspects of Risk Management Implementation for Industry 4.0', Procedia Manufacturing, 11 June, (pp. 1223–1230).

Wang, S. et al. (2016). International Journal of Distributed Sensor Networks, 2016. *'Implementing Smart Factory of Industrie 4.0: An Outlook'*.

Zawadzki, P. and Zywicki, K. (2016). Management and Production Engineering Review. *'Smart product design and production control for effective mass customization in the industry 4.0 concept'*,7(3), 105–112.

Appendix

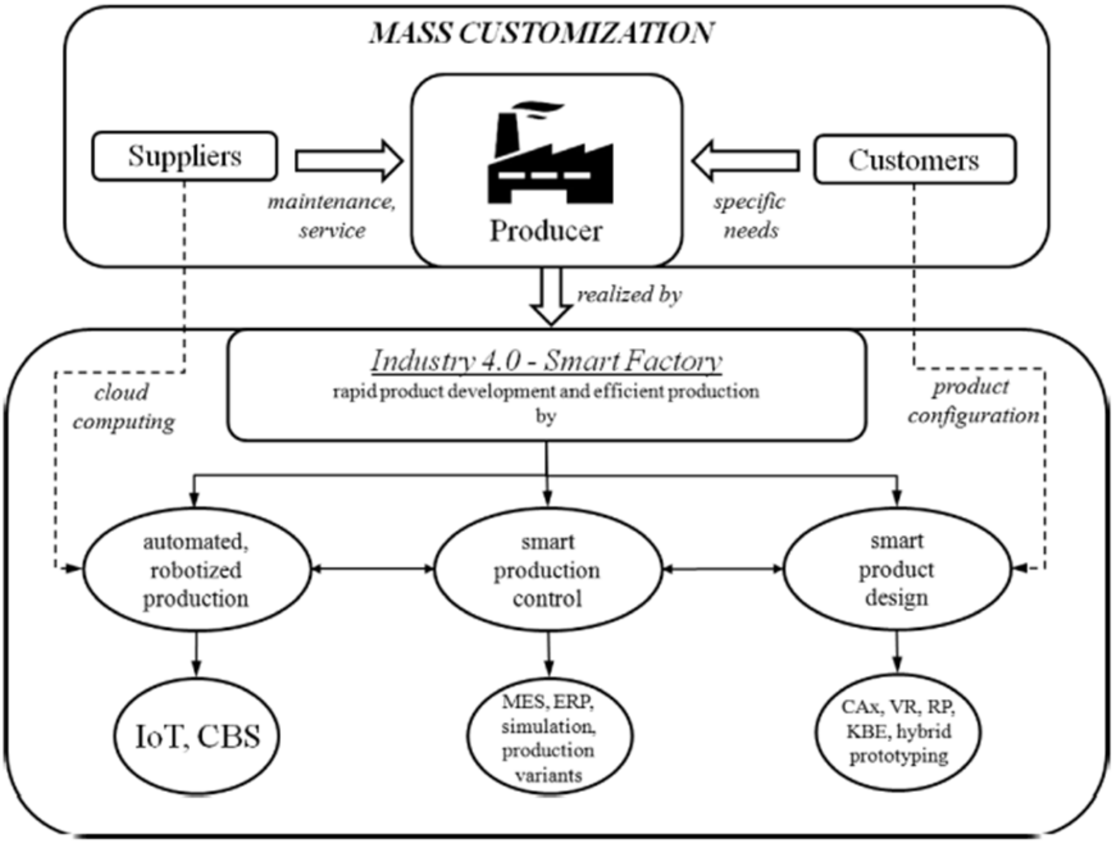

Figure 1. Realization of Mass Customization through Industry 4.0
Zawadzki and Zywicki (2016)

Table 1. Design Principles of Industry 4.0 Components.
Lidong Wang, Guanghui Wang (2016)

Design	CPS	IoT	IoS	Smart Factory
Interoperability	X	X	X	X
Virtualisation	X	-	-	X
Decentralisation	X	-	-	X
Real-Time Capability	-	-	-	X
Service Orientation	-	-	X	-
Modularity	-	-	X	-

Table 2. Characteristic of Industry 4.0. Rüßmann et al.(2015)

No.	Attributes	Discussion
1.	Big Data and Analytics	The collection and comprehensive evaluation of data from many different sources such as production equipment, company and customer management systems are standard to support real-time decision making.
2.	Autonomous Robots	Robots are evolving for even greater utility by becoming more autonomous, flexible, and cooperative. The interaction beten robots and human are more efficient. These robots cost less and have a greater range of capabilities than those used in previous manufacturing.
3.	Simulation	Simulations used in plant operations are more extensively. Real-time data to mirror the physical world in a virtual model are leverage and allows operators to test and optimize the machine settings for the next product before the physical changeover.
4.	Horizontal and Vertical System Integration	Departments, functions, and capabilities are much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains.
5.	The Industrial Internet of Things	Most manufacturing devices enriched with embedded computing and connected using standard technologies. This allows field devices to communicate and interact both with one another and with more centralized controllers, as necessary. It also decentralizes analytics and decision making, enabling real-time responses.
6.	Cybersecurity	The need to protect critical industrial systems and manufacturing lines from cybersecurity threats increases dramatically due to the

		increased connectivity and use of standard communications protocols. So, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential.
7.	The Cloud	Production-related undertakings require increased data sharing across sites and company boundaries. At the same time, the performance of cloud technologies will improve and achieve reaction times of just several milliseconds.
8.	Additive Manufacturing	Additive-manufacturing methods are widely used to produce small batches of customized products that offer construction advantages, such as complex and lightight designs. High-performance in decentralized additive manufacturing systems reduce transport distances and stock on hand.
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. Companies will make much broader use of augmented reality by providing workers with real-time information to improve decision making and work procedures.

Table 3. Comparison of Attributes and Technologies.
Lee, Bagheri and Kao (2015)

	Data source	Today's factory		Industry 4.0	
		Attributes	Technologies	Attributes	Technologies
Component	Sensor	Precision	Smart sensors and fault detection	Self-aware Self-predict	Degradation monitoring & remaining useful life prediction
Machine	Controller	Producibility & performance	Condition-based monitoring & diagnostics	Self-aware Self-predict Self-compare	Up time with predictive health monitoring
Production system	Networked system	Productivity & OEE	Lean operations: work and waste reduction	Self-configure Self-maintain Self-organize	Worry-free productivity

Table 4: Technical Features of Smart Factory Compared with Traditional Production Line. Shiyong Wang, Jiafu Wan, Chunhua Zhang (2016)

Number	Smart factory production system	Traditional production line
1	**Diverse Resources.** To produce multiple types of small-lot products, more resources of different types should be able to coexist in the system.	**Limited and Predetermined Resources.** To build a fixed line for mass production of a special product type, the needed resources are carefully calculated, tailored, and configured to minimize resource redundancy.
2	**Dynamic Routing.** When switching between different types of products, the needed resources and the route to link these resources should be reconfigured automatically and on line.	**Fixed Routing.** The production line is fixed unless manually reconfigured by people with system power down.
3	**Comprehensive Connections.** The machines, products, information systems, and people are connected and interact with each other through the high speed network infrastructure.	**Shop Floor Control Network.** The field buses may be used to connect the controller with its slave stations. But communication among machines is not necessary.
4	**Deep Convergence.** The smart factory operates in a networked environment where the IWN and the cloud integrate all the physical artifacts and information systems to form the IoT and services.	**Separated Layer.** The field devices are separated from the upper information systems.
5	**Self-Organization.** The control function distributes to multiple entities. These smart entities negotiate with each other to organize themselves to cope with system dynamics.	**Independent Control.** Every machine is preprogrammed to perform the assigned functions. Any malfunction of single device will break the full line.
6	**Big Data.** The smart artifacts can produce massive data, the high bandwidth network can transfer them, and the cloud can process the big data.	**Isolated Information.** The machine may record its own process information. But this information is seldom used by others.

The ingredients for Industry 4.0			
Instrumented	**Interconnected**	**Inclusive**	**Intelligent**
Data Devices contain sensors, actuators and software that generate data	**Connectivity** An information network connects devices together; gathers and processes the data either at the edge of the network or centrally – selectively	**Context** Industry knowledge, data external to the network (weather etc.) adds context to the data	**Decision Making** Machine learning, predictive analytics and cognitive computing makes sense of the data; decentralized decision making, move towards autonomy

What Industry 4.0 enables		
Design	**Make**	**Use**
Integrate - use of existing products by equipping them with sensors to bring them into the connected environment **Predict** - design new products based on utilisation of existing products and market reaction to concepts **Innovate** - insight from sensor data can guide equipment usage and new product or service design based on customer use and use across a network	**Optimise** - predictive maintenance of production lines optimises uptime and maximises throughput **Fulfil** - meet market demands by providing what is most utilised **Extend** - machines will come with intelligence pre-built. The applications for those product-service hybrids will become revenue streams **Employ** - new roles for product and experience designers, application developers, data scientists equipment/network production, implementation and support.	**Satisfy** – predictive maintenance of products assures optimal usability and availability, optimised supply chains assure availability **Safety** – hazardous tasks and environments are delivered by robots. **Sensory** – new ways for humans to interact digitally with machines through voice, sight, touch and movement.

Figure 2. A framework for Industry 4.0. Scott Stockwell (2017)