SMART MANUFACTURING: ITS CHALLENGE AND FUTURE IMPLEMENTATION IN MALAYSIA

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KUALA LUMPUR

2017

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SUBMITTED TO THE
FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA, IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF ENGINEERING
(MATERIAL & TECHNOLOGY)

2017

UNIVERSITY OF MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: **Muhammad Hazrie Bin Ibrahim**

Matric No: **KMB150003**

Name of Degree: **Master of Engineering (Material and Technology)**

Title of Project Paper/Research Report/~~Dissertation/Thesis~~ ("this Work"):

Smart Manufacturing: Its Challenge and Future Implementation in Malaysia

Field of Study: **Design Manufacturing**

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SMART MANUFACTURING: ITS CHALLENGE AND FUTURE IMPLEMENTATION IN MALAYSIA

ABSTRACT

Smart manufacturing, which is also known as a fourth revolution in the manufacturing industry have been identified as the way forward for Malaysia industries to improve competitiveness through the introduction of cutting-edge ICT technologies and the convergence with the existing manufacturing technologies. However, the blueprint of these evolutions, technological borders and the application of framework are not yet specified. Therefore, the adoption of this paradigm change still requires more research to further analyze the potential challenge and implementation of Industry 4.0 and Smart Manufacturing in Malaysia. Towards this goal, this paper seeks to review the implementation of smart manufacturing in other developed countries such as Germany, USA, Japan and Republic of Korea by identifying strategies established to support the implementation of smart manufacturing in their respective countries. Our next objective is to explore the feasibility of implementing Industry 4.0 in manufacturing companies in Malaysia by identifying the potential challenge of implementation, as well as the opportunities and trade-offs that these companies would expect from an implementation of these integrated technologies.

Keywords: Smart manufacturing, Industry 4.0, competitiveness, challenges, implementation

ABSTRAK

Perkilangan pintar ('Smart Manufacturing'), juga dikenali sebagai Revolusi Perindustrian Keempat (IR 4.0) dalam sektor pembuatan telah dikenalpasti sebagai langkah ke hadapan untuk industri-industri di Malaysia bagi meningkatkan daya saing melalui pengenalan teknologi ICT yang canggih dalam teknologi pembuatan yang sedia ada. Walau bagaimanapun, pelan induk perubahan ini, penggunaan teknologi dan pemakaian rangka kerja masih belum ditentukan lagi. Oleh itu, penerapan perubahan paradigma ini masih memerlukan lebih banyak penyelidikan untuk menganalisis potensi cabaran dan pelaksanaan Revolusi Perindustrian Keempat dan perkilangan pintar di Malaysia. Untuk mencapai matlamat ini, kertas kerja ini bertujuan untuk mengkaji pelaksanaan perkilangan pintar di negara-negara maju lain seperti Jerman, Amerika Syarikat, Jepun dan Korea Selatan dengan mengenal pasti strategi yang dilancarkan untuk menyokong pelaksanaan perkilangan pintar di negara-negara tersebut. Objektif seterusnya ialah meneroka tahap kebolehlaksanaan Revolusi Perindustrian Keempat di syarikat-syarikat perkilangan di Malaysia dengan mengenal pasti cabaran yang mungkin di hadapi untuk pelaksanaan, serta peluang yang diharapkan oleh syarikat-syarikat ini daripada pelaksanaan teknologi bersepadu ini.

Kata kunci: Perkilangan pintar, Revolusi Perindustrian Keempat, daya saing, cabaran, pelaksanaan

ACKNOWLEDGEMENTS

Alhamdulillah, all praise to Allah, the almighty for granting me the courage and strength to be able to achieve this work successfully.

I would like to offer my special thanks to all who made this research project possible. First and foremost, I wish to express my special gratitude to my supervisor Dr. Farazila Yusof for her encouragement and thoughtful guidance throughout the completion of the research.

I also want to express my deep thanks to my senior in Malaysia Investment Development Authority (MIDA), Muhammad Haikal Samsudin for sharing his insightful knowledge and valuable advice during the whole period of this research. Massive thanks to all my friends, juniors, seniors, and other respondents which have spent their precious time to answer my entire questionnaire. Also, special thanks to Mr. Kim Sung Ho, my boss in Hyundai Corporation for his kind understanding and support. I also appreciate the financial support from Ministry Of Higher Education in pursuing my master study.

Above all, no words are eloquent enough to express my fondest gratitude to both my parents, Ibrahim Bin Abdullah and Norida Binti Daipi for all those tireless efforts to raise me well. Not forgotten to my family and family-in-law members, thank you for the understanding that incentivized me to strive towards my goal. My special appreciation to my beloved wife, Siti Norazrina Binti Nor Sabri, who always provide great encouragement and support through the journey. To my precious son, Aqeel Nur Hakim who always stayed with me until midnight and cheers me up from asleep while writing my research paper, I love you and I appreciate all your patience and understanding during babah’s study. As promised, let’s go to LEGOLAND!

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percentage
$	US Dollar
11MP	Eleventh Malaysia Plan
ACA	Accelerated Capital Allowance
AEA	Automation Equipment Allowance
AM	Additive Manufacturing
AMP	Advanced Manufacturing Partnership
CIM	Computer Integrated Manufacturing
CM	Cloud Manufacturing
CNC	Computer Numerical Control
CPS	Cyber-Physical Systems
CSF	Connected Smart Factory
DISF	Domestic Investment Strategic Fund
E&E	Electrical and Electronic
ERP	Enterprise Resource Planning
GDP	Gross Domestic Product

GNI	Gross National Income
Hi-Tech	High-Technology
HPC	High-Performing Computing
I4.0	Industry 4.0
ICT	Information and Communications Technology
IoT	Internet of Things
IoS	Internet of Services
IPv6	Internet Protocol version 6
IT&SW	Information technology and Software
ITU	International Telecommunication Unit
KRW	Korean Republic Won currency
LLC	Limited Liability Company
LoA	Levels of Automation
Mbps	Megabits per second
MES	Manufacturing Execution Systems
METI	Ministry of Economy, Trade and Industry (Japan)
MIDA	Malaysian Investment Development Authority
MITI	Ministry of International Trade and Industry (Malaysia)

MSIP	Ministry of Science, ICT and Future Planning (South Korea)
MOTIE	Ministry of Trade, Industry and Economy (South Korea)
MNC	Multinational Corporation
M&E	Machinery and Equipment
NIST	National Institute of Standards and Technology (US)
NNMI	National Networked Manufacturing Innovation
NRI	Networked Readiness Index
PAC	Penang Automation Cluster
PLM	Product Lifecycle Management
PSDC	Penang Skills Development Centre
R&D	Research and development
ROI	Return of Investment
RTMIIS	Real-Time Manufacturing Information Integration Service
SF	Smart Factory
SME	Small and Medium Enterprises
SMLC	Smart Manufacturing Leadership Coalition
STEM	Science, Technology, Engineering and Mathematics

CHAPTER 1: INTRODUCTION

This chapter presents the background of the study by providing a brief introduction to the topic. This is followed by the scope and limitation of the study, specification of the problem, the objective of the research and the selected research questions.

1.1 Background of study

Manufacturing continues to be a vital economic thrust in Malaysia, employing around 2.45 million people and contributing to over 23% of the nation's GDP in 2016 (Department of Statistics Malaysia). The Malaysia government aims to transform their economy from labor-driven economy into a knowledge economy based on the development of high tech products with a high added value. Thus, for policy makers to support manufacturing industries to compete globally and remain competitive, it's important for Malaysia to implement the smart manufacturing concept in next industrial revolution, which also better known as Industry 4.0.

Industry 4.0 aims to increase the digitalization of manufacturing processes and supply chains, facilitating the communications between humans, machines and products, thus enabling real time access to manufacturing processes data and the performance of autonomous work processes along value chains. New trends of Smart Manufacturing technology such as Internet of Things (IoT), Internet of Services (IoS), Cyber-Physical Systems (CPS), Big Data Analytics, Advanced intelligent (AI), Cloud Manufacturing, Additive Manufacturing, Cyber Security and Autonomous Robots are becoming more and more important.

1.2 Problem statement

Industry 4.0 is still in an early development phase and it promises to bring remarkable benefits to the manufacturing industry around the world when employing the Smart Manufacturing concept in large organizations and their supply chains. Malaysia was ranked among the top high-technology exporters in the world league table, but in terms of the adoption of software, technology and integration, Malaysia still lags behind (MIDA, 2016). Therefore, in order for government to overcome this deficiency, the government believed that Smart Manufacturing is one of a solution that could make manufacturing companies in Malaysia stay competitive with the rapid changes in the sector.

However, there is a risk of a miss-match when trying to introduce Industry 4.0 to Malaysian manufacturing companies as the concept, with its pursuit of becoming flexible and achieving the desired purpose, is mainly being developed around large manufacturing firms in highly industrialized nations. Therefore, it is of great importance to see if this predicted change within the manufacturing industry will be feasible for the manufacturing companies in Malaysia as well to ensure that they are being considered and approach in an accurate way for a successful implementation of Industry 4.0 and Smart Manufacturing in Malaysia.

1.3 Objective

1. To review the implementation of smart manufacturing in developed countries likes USA, Germany, Japan and South Korea.

a) What are strategies or policies established by developed countries to enhance and support implementation of smart manufacturing in their countries?

b) What are key technology areas that are focused on smart manufacturing?

2. To explore the feasibility of implementing Smart Manufacturing in Malaysia manufacturing industry.

a) What are the potential challenges that manufacturing companies in Malaysia might face with the implementation of Smart Manufacturing?

b) How do the potential challenges, benefits and trade-offs affect the feasibility of adopting Smart Manufacturing in Malaysia manufacturing industry?

1.4 Scope and limitations

The scope of this study will focus on the readiness of manufacturing companies in Malaysia in terms of manufacturer's perspective for implementing Industrial 4.0 and Smart Manufacturing. While conducting a research study, we realized that we might face limitation on acquiring proper information or data since the roadmap of these evolutions and the application of framework are not yet specified. Furthermore, there is not much study related to implementation of Industry 4.0 in Malaysia have been conducted so far.

We have conducted a short questionnaire in order to check the current status of implementation Smart Manufacturing in Malaysia and figure out the possible challenges they might encounter for this transformation. Nevertheless, from the interpretation of the results, there are a several factors which need to be considered. Firstly, the majority of respondents were working-level personnel and not a high level management as we targeted earlier who might have a more holistic and probably have better oriented perspective of the company's direction. Besides that, the respondents come from different size of companies, not only specifically for SMEs. Hence, there were significant differences in their perception towards implementation of Industry 4.0. Besides that, none of them considered themselves an expert in the area of Industry 4.0. Therefore, the level of knowledge and experience greatly varies among all of the respondents. Last but not least, the numbers of respondents were also limited.

1.5 Organization of report

This report is organized according to chapter by chapter. Each chapter represents different topics which related to this study. Below are the descriptions of the chapter and its brief contents.

- Chapter 1

Chapter 1 presents the background of the study by providing a brief introduction to the topic and an overview of related facts of what have led up to what is claimed to be the Industry 4.0 or Smart Manufacturing. This is followed by a specification of the problem, the objective of the research and the selected research questions is addressed.

- Chapter 2

Chapter 2 provides extensive background information on previous studies or current research which related to the Industry 4.0 and Smart Manufacturing, global trends of Smart Manufacturing technology, Smart Manufacturing key components and core outcome of implementing Industry 4.0.

- Chapter 3

Chapter 3 describes the methodology and method used so as to provide the scientific value of the given research. In this section we discuss and support our chosen research design, the reasons that motivated us to use an inductive approach with a qualitative research method by conducting a questionnaire to relevant persons in an industry which focusing on key manufacturing sector.

- Chapter 4

Chapter 4 represents the survey findings, where we show the main results of this research, followed by the analysis where we apply the theory of Industry 4.0, presented in the framework, with the findings of our research in order to identify the challenges, benefits and trade-offs that manufacturing companies in Malaysia might face with an implementation of Smart Manufacturing.

- Chapter 5

Chapter 5 concludes and summarized the overall results, which also answers our research question of the feasibility of implementation Industry 4.0 for manufacturing companies in Malaysia, based on the benefits, trade-offs and barriers presented in the analysis and we then finish off with recommendation for future research.

CHAPTER 2: LITERATURE REVIEW

This chapter provides extensive background information on previous studies or current research which related to the Industry 4.0 and Smart Manufacturing, global trends of Smart Manufacturing technology, Smart Manufacturing key components and core outcome that are expected from implementing Industry 4.0.

2.1 Introduction of Malaysia Manufacturing Industry

Since its independence in 1957, Malaysia has achieved an impressive development of its manufacturing sector and its overall economy. The share of manufacturing in Malaysia's gross domestic product (GDP) rose from 8.8% in 1970 to 22.8% in first quarter of 2017, while the share of manufactured goods in total trade has risen from around 25% in the early 1980s to around 87.9% today. Malaysia was ranked 11th in the world league table of high-tech exporters (Refer figure 2.1) and 43.87% of its manufactured exports are high-tech products (World Bank, 2016).

High-technology exports (current US$)

	Country	2014	2012	2011	2010
1	China	558,605,991,980	505,645,680,350	457,106,558,431	406,089,687,684
2	Germany	199,718,151,684	187,015,792,743	183,371,439,118	158,507,039,742
3	Hong Kong SAR, China	192,718,805,476	841,460,390	805,496,960	1,105,610,241
4	United States	155,640,595,588	148,330,989,468	145,638,600,147	145,932,689,277
5	Singapore	137,369,116,389	128,239,439,593	126,434,946,962	126,981,502,643
6	Korea	133,447,400,828	121,312,606,727	122,021,442,532	121,478,141,990
7	France	114,697,237,252	108,585,750,298	105,761,429,426	99,735,768,592
8	Japan	100,954,836,424	123,411,773,351	126,477,503,562	122,102,186,970
9	United Kingdom	70,652,924,421	67,786,969,582	69,611,885,161	60,172,818,879
10	Netherlands	70,308,349,003	63,963,116,660	67,147,867,601	59,509,788,717
11	Malaysia	63,376,041,042	61,228,924,357	61,126,964,506	59,331,817,835
12	Switzerland	55,906,710,140	50,098,542,757	50,124,292,139	42,679,710,697
13	Mexico	49,402,709,617	44,021,894,972	40,795,383,584	37,657,285,550
14	Belgium	43,698,592,018	36,503,921,134	34,680,646,884	31,948,749,412
15	Thailand	34,992,376,969	33,767,674,064	33,264,733,346	34,156,221,484
16	Canada	31,552,262,953	29,087,234,635	25,017,006,457	23,963,441,244
17	Vietnam	30,863,791,585	16,259,339,193	9,118,403,941	4,020,110,739
18	Italy	30,744,972,831	27,525,718,963	31,191,607,345	26,419,456,970
19	Philippines	23,839,225,492	20,795,049,384	12,949,169,027	16,071,867,452
20	Czech Republic	23,084,215,820	22,007,809,307	23,365,827,816	17,468,785,927

Source: World Development Indicators (WDI), July 2016

Figure 2.1: High technology export list (World Development Indicators, 2016)

As impressive as these achievements appear, they leave much to be desired. Malaysia has yet to achieve high-income economy. If we look back in the past, Malaysia started out with somewhat almost same levels of gross domestic product (GDP) per capita as Japan, South Korea and Singapore in the 1970s. However, the three countries have since gone on to become high-income economies, while Malaysia still remains an upper-middle-income economy, with a Gross National Income (GNI) per capita income around $9850 (Bank Negara Malaysia, Department of Statistics Malaysia and the World Bank, 2016).

Between the 1970s and the mid-90s, Malaysia was seen as the preferred manufacturing location for many MNCs. Subsequently, with the development of the manufacturing sector in other locations such as China, Myanmar and Vietnam, there were concerns about Malaysia’s attractiveness as a manufacturing hub. Malaysia is no longer considered a low cost location for setting up manufacturing operations. Whilst Malaysia continues to retain and attract investments in this sector due to the highly diversified economy, strong manufacturing foundation, the availability of good infrastructure, highly experienced and skilled talent, proactive government policies, and availability of generous tax incentives, cost continues to be a one of the major concerns.

Furthermore, SMEs are fundamental elements of the Malaysian economy, generating not less than 30 percent of the overall gross domestic product (GDP) and employing almost 60 percent of the total labor workforce in the country. Moreover, SMEs account for the majority of business establishments (97.3%) in Malaysia. So, as we go along, a large part of new technology adoption will be driven by SMEs. However, according to the Malaysia Productivity Corporation, ICT adoption by SMEs in Malaysia is a mere 10%. By contrast, ICT adoption by other developed countries stands at 50%. Moreover, in the E&E and high-tech sector, where it has achieved world competitiveness in certain market segments, Malaysia still mainly dependent on foreign expertise especially for core technologies, hence not being able to capture the most lucrative parts of the value chain (Rasiah 2004; 2010).

The Malaysia government aims to transform their economy from labor-driven economy into a knowledge economy based on the development of high tech products with a high added value. For Malaysia to achieve high-income nation status by 2020, manufacturing remains a key sector for sustainable growth under the 11MP. Malaysian Investment Development Authority (MIDA) has formulated 3+2 strategy which focuses on the development of three main sub-sectors, namely electrical and electronics, chemicals and machinery and equipment industries; and two high potential growth sub-sectors, namely aerospace and medical devices (Refer figure 2.2). These targeted sub-sectors have been identified as a high value-added product which could contribute to the significant increase in sales value. Therefore, MIDA believed that this strategy could help to revamp the manufacturing sector in the country. Furthermore, MIDA is also conducting a study on the future of manufacturing based on these 3+2 subsectors in order to better understand the needs and challenges of SMEs in adopting automation.

TOTAL APPROVED INVESTMENTS FOR THE 3+2 SUBSECTORS FOR 2016

No.	Industry	No. of Projects	Investment (RM Billion)
1.	Electrical & electronics	107	9.2
2.	Medical devices	41	2.9
3.	Chemical & chemical products	69	3.1
4.	Machinery & equipment	88	1.5
5.	Aerospace	9	1.6
	Total	314	18.3

Figure 2.2: Approved investments for 3+2 subsectors for 2016 (MIDA, 2016)

APPROVED PROJECTS IN THE MANUFACTURING SECTOR (1980-2016)

Industry	Total		
	Number of projects	Employment	Investment (RM Billion)
Electronics & Electrical Products	5,465	1,086,730	236.0
Petroleum Products (Inc. Petrochemicals)	391	27,793	171.3
Basic Metal Products	1,175	133,049	143.0
Chemical & Chemical Products	2,030	96,017	93.7
Transport Equipment	1,916	193,690	72.0
Non-Metallic Mineral Products	1,475	119,262	60.8
Food Manufacturing	2,078	170,877	48.5
Natural Gas	9	2,482	31.2
Fabricated Metal Products	2,344	158,435	31.1
Paper,Printing & Publishing	899	73,494	31.1
Machinery & Equipment	2,196	141,044	28.3
Wood & Wood Products	1,634	259,904	24.6
Rubber Products	1,350	195,682	22.7
Plastic Products	1,885	127,894	21.5
Textiles & Textile Products	1,547	217,550	19.7
Scientific & Measuring Equipment	453	53,896	15.0
Furniture & Fixtures	1,217	144,243	7.2
Miscellaneous	552	53,781	4.4
Beverages & Tobacco	192	15,015	4.1
Leather & Leather Products	99	11,535	0.5
Total	28,907	3,282,371	1,566.6

Figure 2.3: Approved project in the manufacturing sector (MIDA, 2016)

In order to develop further manufacturing industries in Malaysia, Malaysian Investment Development Authority (MIDA) identified that Smart manufacturing is the way forward to Malaysia industries and foresee an opportunity to increase their competitiveness for emerging economies like Malaysia. The 11th Malaysia Plan (2016-20) has outlined the future direction of the country's economic development, one driven by enhanced productivity through information communications technology and smart manufacturing.

Recognizing the challenge of transitioning towards Industry 4.0, Ministry of International Trade and Industry (MITI) is in the midst of formulating the National Industry 4.0 Blueprint, which expected to be ready by first quarter (Q1) of next year and establishing a National Industry 4.0 Taskforce to spearhead the government's policy and strategy in this area.

2.2 Three industrial revolutions and the introduction of Industry 4.0 – The Fourth Industrial Revolution

Since the end of the 18th century, the world has gone through different industrial revolutions that have changed and reshaped industrial production, societies and businesses. The first Industrial Revolution (Industry 1.0) originated in the late 18^{th} century which introduced the steam power engines enabling machine-based production facilities. Meanwhile, the second Industrial Revolution (early 20th century) represents a mass production system through the adoption of the production facilities driven by electricity. The third Industrial Revolution (early 1970s), also known as Industry 3.0, refer as an expansion of automated production process fields through the supply of electronic equipment and Information Technologies (IT). And now, we have reached to the forth Industrial Revolution (Industry 4.0) which refers as a strategy designed to construct a communication system between production equipment and products based on hyper-connected technology and integrate the entire production processes (ACATECH, Apr. 2013).

The idea behind this term is that, the first three industrial revolutions came about as a result of mechanization, electricity and IT. Now, the introduction of the IoT and CPS into the manufacturing environment is ushering in a 4th Industrial Revolution. While the first three revolutions had a major impact on the internal production processes on a 'shop-floor'-level, the fourth revolution is anticipated to have an impact that stretches, not only across departments internally, but also externally across actors within the supply chain to form an integrated value chain across companies (Figure 2.4) (Engineers Journal, 2014; Forstner & Dümmler, 2014).

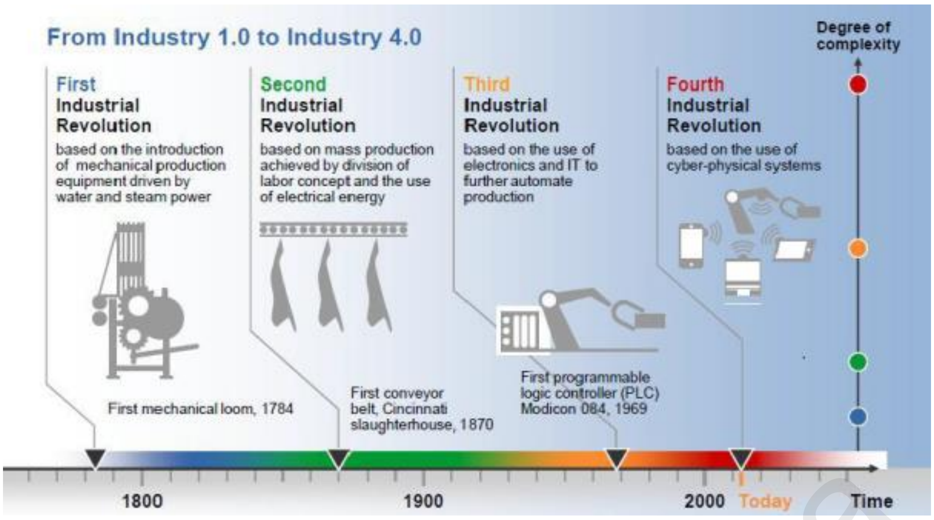

Figure 2.4: “From Industry 1.0 to Industry 4.0” (Carroll, D., 2014)

In spite of the great changes that Industry 4.0 is expected to bring to the manufacturing industry, different opinions arise as to whether it actually will be a revolution or not, and many experts prefer to speak of it as an evolution rather than a revolution due to the timescale involved (Albert, 2015; Kagermann, 2015). Albert (2015) argues that companies are probably more likely to implement the technology step by step and phase by phase, along with it being developed and available to the market.

The manufacturing industry will be subject to radical changes in the next decade. Future manufacturing processes will include more flexible production lines and faster machines that are more accurate, efficient, smarter, and offer a greater IT-connectivity to ERP (Enterprise Resource Planning)-systems and manufacturing execution systems (Hoske, 2015). Industry 4.0 implies contextual and design changes in the Supply Chain (Delfmann & Klaas, 2005).

The contextual changes will be outlined by the new high technological characteristics that will provide managers with real-time information across the entire supply chain, resulting in for instance a decreased uncertainty of demand and the possibility of an increased customization of products, while the design variables on the other hand, among other things, include the creation of new business models, decentralization of organizations' structure, integration and coordination mechanism (Delfmann & Klaas, 2005; Sommer, 2015). Barriers, benefits and trade-offs are expected when implementing Industry 4.0 to the manufacturing industry, especially if tested in Small and Medium Enterprises since these differ from the larger firms that have been the focus of the initial research (Sommer, 2015) and furthermore, the availability to implement new technologies is linked to the industry type and company size (Brettel et al., 2014).

2.3 Industry 4.0 emergence

Industry 4.0 is a developing concept originated in Germany in 2011 that has gained attention from the manufacturing industry, academia and government, building high expectations around its outcomes as Industry 4.0 is committed to increase the performance levels of the manufacturing industry by synchronizing industrial automation equipment (Chung, 2015).

Economic, environmental and social impacts on the manufacturing industry are expected when implementing i4.0. From the economic perspective, Industry 4.0 aims at cost and risk reductions, performance improvements and flexibility (Leonard, 2015; Sommer, 2015), increased productivity (Chung, 2015; Schuh, Potente, Wesch-Potente, Weber, & Prote, 2014), virtualization of the process and supply-chain, mass customization (Brettel et al., 2014), individualization of demand or batch size one (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014) and creating resilient industries (Kagermann, 2015; Lee, Bagheri, & Kao, 2015).

From the environmental perspective, i4.0 use fewer resources more efficiently, and configure logistics routes and capacity utilization more efficiently (Kagermann, 2015; Wang, Wan, Li, & Zhang, 2016). Finally, from the social perspective individual workers will benefit from i4.0 as they will manage their own work time and will be the centre of the working environment, therefore is essential for workers to develop skills that fit the new needs of i4.0 (Brynjolfsson & McAfee, 2012; Kagermann, 2015).

I4.0 enables organizational and supply chain interoperability, incorporating smart infrastructure and production processes (Brettel et al., 2014; Hermann et al., 2015). To gain access to the benefits that i4.0 offers, organizations need to redesign processes and make investments in technology. For some manufacturers, the forthcoming i4.0 era is the logical next step, while for others i4.0 represents new and more difficult challenges as their organizations are still struggling with the innovative technologies that the previous revolution conveyed (Brynjolfsson & McAfee, 2012; Jennings, 2015).

Hermann et al. (2015), defined Industry 4.0 as:

"A collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, Cyber-Physical Systems (CPS) monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things (IoT), CPS communicate and cooperate with each other and humans in real time. Via the Internet of Service (IoS), both internal and cross-organizational services are offered and utilized by participants of the value chain."

2.4 Global trends of Smart Manufacturing Technology

In this chapter, the strategies established by developed countries like Germany, USA, Japan and Korea to enhance and support implementation of smart manufacturing in their respective countries were reviewed along with the current status and future plans of Malaysia government, which mainly from the Ministry of International Trade and Industry (MITI) and Malaysian Investment Development Authority (MIDA).

Major countries are keen to develop smart manufacturing technologies. Although the term “Industry 4.0” (or more correct “Industrie 4.0”) is Germany, the different components included in the concept are not all developed in Germany, and some of them have already been in use for quite some time in other countries as well, such as the USA for instance (Kang et al., 2016). USA has launched the Advanced Manufacturing Partnership (AMP) in 2011, an effort to revamp their manufacturing industries in order to stay ahead. USA invested US$2.2 billion for AMP in 2013 to encourage the return of domestic manufacturing and regain its leading position in the manufacturing industry.

Meanwhile, Japan began the Industry Revitalization Plan in 2013 to revamp the manufacturing industry with equipment and R&D investments. South Korea devised is Manufacturing Innovation 3.0 strategy in 2014 to help SMEs establish smart and optimized production processes (Ming, 2015). Although there are different terms used by highly industrialized nations around the world to develop smart manufacturing technology, but they are working towards the same goal: to gather the latest and most advanced technologies in order to enhance engineering decision-making, based on real time information, through the application of various new cutting edge ICT technologies that are being deployed with the already established manufacturing technologies (Kang et al., 2016).

2.4.1 Germany

Industry 4.0 is a strategic initiative of the Germany government that was adopted as part of the "High-Tech Strategy 2020 Action Plan" in 2011 (Kagermann, Wahlster, Helbig, 2013). The main objective of this concept is to strengthen the competitiveness of the manufacturing sector in the country through the convergence between industrial production and Information and Communication Technologies (ICT).

Industry 4.0 refers to the technological evolution of embedded systems to cyber-physical system. This term involves the use of three technologies called Internet of Things (IoT), Internet of Services (IoS) and Cyber-Physical systems (CPS) that when convened together in production sites engenders the application of Smart Factories (SF). Figure 2.5 and figure 2.6 show basic conceptual diagrams for the application of Industry 4.0 and smart factory. Figure 2.3 presents the relationship of IoT and IoS around a smart factory based on CPS.

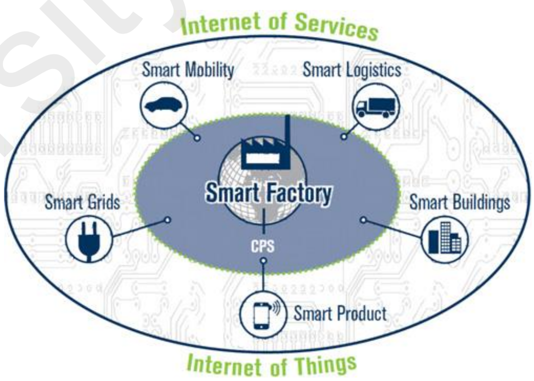

Figure 2.5: Industry 4.0 and smart factories as part of IoT and IoS (Kagermann, Helbig, Hellinger, and Wahlster, 2013)

Meanwhile, figure 2.6 shows more specific diagrams, which consist of IoT that acquire connectivity at a production site, service platforms that connected IoT and IoS while performing CPS functions, IoS that connect applications to business processes and other related applications for each area.

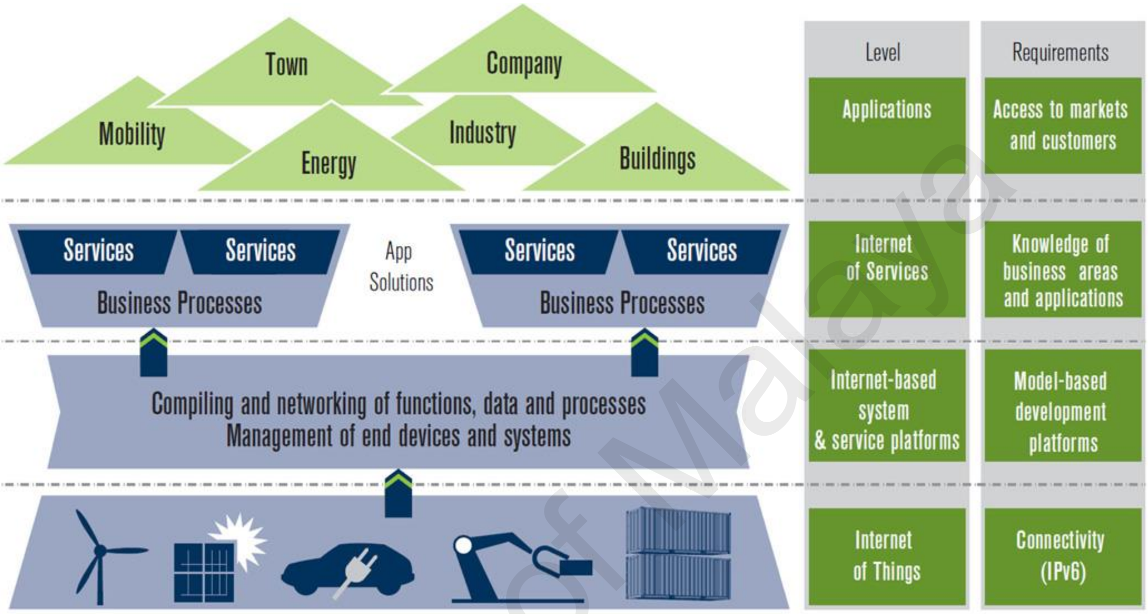

Figure 2.6: Reference architecture for connecting IoT and IoS (Kagermann, Helbig, Hellinger, and Wahlster, 2013)

With the foundations of smart factory based on IoT and CPS, various system technologies and architectures have emerged over the past few years. The research and development project related to smart manufacturing in Germany pay particular attention to key technology task, such as CPS, it, IoS, Big Data, Cloud Computing, Sensor and others. Moreover, this report indicated that CPS, IoT and IoS should be set up first to integrate these existing complex systems, and other various IT technologies such as big data, sensors and cloud computing (Kang et al., 2016).

2.4.2 The U.S.

USA has launched the Advanced Manufacturing Partnership (AMP) in 2011, a national effort which gathers industry player, universities, and the federal government to invest in the emerging technologies that will create high quality manufacturing workforce and enhance global competitiveness. Investing in new technologies, such as information technology and nanotechnology, will support the creation of better jobs by helping U.S. manufacturers reduce costs, enhance quality, and expedite product development (NIST, 2011).

Besides that, the government launched Smart Manufacturing Leadership Coalition (SMLC), which is non-profit organization consist of manufacturers, suppliers, technology firms, government agencies and universities which all have the common target of advancing the way of thinking behind Industry 4.0 via an open, smart manufacturing platform for industrial-networked information applications. The U.S. has established a National Network for Manufacturing Innovation with a total US$1 billion (RM4 billion) of public funding for the purpose of research and development, and implementing programs related to Smart Manufacturing technology (Kang et al., 2016).

The research and development projects related to smart manufacturing in the U.S. concentrate on the key technology task, including CPS, IoT, big data analytics, cloud computing, sensor and additive manufacturing (Kang et al., 2016). The meaning of each core technology for smart manufacturing is summarized as follows.

Table 2.1: Definition of core technology for smart manufacturing

Core technology	Meaning
Internet of Things	System of interrelated computing devices, mechanical and digital machines and the ability to transfer data over a network without requiring human interaction.
Big Data Analytics	Strategy of analyzing large volumes of data, or big data.
Cyber-physical System	Transformational technologies for managing interconnected systems between its physical assets and computational capabilities.
Cloud Computing	The virtualization and central management of data center resources as software-defined pools.
Additive manufacturing	Process by which digital 3D design data is used to build up a component in layers by depositing material.

2.4.3 Japan

Japan began the Industry Revitalization Plan in 2013 to revamp the manufacturing industry with equipment and R&D investments. In order to further expedite its structural reforms, the government revised its growth strategy in June 2014. The objective of this revised strategy is to establish a world-leading business environment and reinforcing workforce as well as promoting private sector's innovations. One of the strategies to promote innovation of science and technology and develop infrastructure that links innovation with new business by establishing a "National System" that create business from innovate technology seeds, including through (i) reforming functionality of R&D institutes to enhance activities to link universities with business, (ii) allowing researchers to hold concurrent posts at universities and R&D institutes, and (iii) reforming employee invention system in order to incentivize both employees and companies. Another strategy, the government plans to establish the "Robotic Revolution Initiative Council" to create a 5 year plan with the aim of addressing social challenges and realizing new industrial revolution by robots (METI, 2014).

As we well-aware, Japan has long been a powerhouse in the manufacturing industry and established as one of the most advanced countries in robotics and manufacturing. Now, same like other highly industrialized nations, Japan is positioning itself to introduce next generation smart manufacturing. However, Japan is still lagging behind Germany and the US in terms of smart manufacturing preparedness and implementation, but Japanese companies are highly optimistic about the potential for Industry 4.0 and believes that connected manufacturing will strengthen their competitiveness, and that advances within this technology will help them stave off foreign competition (McKinsey & Co report, 2016).

Recognizing the challenge of transitioning towards this new phase, the government launched a new growth blueprint, the Japan Revitalization Strategy 2016. Based on the strategy, efforts will focus on the promotion of a "fourth industrial revolution" which target advancing industry through information technology and artificial intelligence. Because of rapid demographic changes in Japan, the government sees an urgent need to boost the manufacturing industry to make sure future generations can sustain a society with a higher percentage of senior citizens. The Ministry of Economy, Trade and Industry (METI) have highlighted the need for Japanese companies to embrace the digital revolution in manufacturing, especially in a way that can help usher SMEs into the new age of manufacturing. There is a strong focus on furthering collaboration and information exchange, and Japanese companies have so far had a strong interest in studying the recent developments in Germany and the United States (Petter, 2017).

There are a few common insights that Japanese companies see as key applications that are enabled through the introduction of Industry 4.0 related initiatives. At an overview level, big data in the industrial environment is showing great promise when it comes to optimizing the production process, and giving the production managers key insights into huge amounts of data that was previously very difficult to collect, let alone process. This includes various areas such as general quality improvement, energy savings and uptime of the production line itself. As for the production process, one key area highlighted in Japan is predictive maintenance (Petter, 2017). It uses a combination of sensors and machine learning algorithms to predict when equipment, inventory or goods will fail. In summary, by being able to better predict when tools or machine need to be recalibrated or replaced, countermeasures and early warning systems can now more easily be implemented as a result of increased data availability. Furthermore, costs for maintenance can be reduced as well.

2.4.4 South Korea

In 2014, Korean government established the 'Manufacturing Industry Innovation 3.0' strategy for a new transformation of Korean manufacturing industries, which is similar to the Industry 4.0 of Germany and Smart Manufacturing in the U.S. The objective of Manufacturing Industry Innovation 3.0 strategy is to introduce innovation to the manufacturing process, including expanding the use of smart factories and developing key technologies related to the Internet of Things (IoT), CPS and Big Data. Big Data refers to data processing, data collection and data sharing that can be used for data analysis and prediction (Kim, 2015). The strategies and framework to prepare South Korea for the 4th industrial revolution is undertaken by the Ministry of Science, ICT and Future Planning (MSIP) and the Ministry of Trade, Industry and Economy (MOTIE).

Innovation in Manufacturing 3.0 aims to invest KRW200 billion ($172 million) annually from 2015 to 2020 to facilitate the building of 1,500 smart factories by 2020. The main difference between the Innovation in Manufacturing 3.0 and foreign equivalents developed in Germany and the U.S. is that the former prioritizes the technological development and standardization of indigenous technologies, whereas the Korean government's Innovation in Manufacturing 3.0 stresses government provision of support for local small and medium enterprises (SMEs) with a view to disseminating smart factory technologies among local SMEs. Under the "Voluntary Participation Principle" initiative, Innovation in Manufacturing 3.0 seeks SMEs that plan to invest in upgrading their production facilities and would contribute 50% of the investment. The government typically issues KRW50 million ($43,115) for each selected SME and the SME is expected to contribute another KRW50 million (Kim, 2015).

Figure 2.7 shows major strategies and comprehensive assignments in order to support the smart innovation in the manufacturing industry. The key technologies have been identified for Smart Manufacturing including CPS, IoT, Big Data, Cloud Computing, Smart Energy, Sensor, Additive Manufacturing (3D Printing) and Hologram (Kang et al., 2016).

4 strategies	13 assignments
Smart manufacturing proliferation	Distribute proliferate smart factories Develop 8 smart manufacturing technologies Reinforce manufacturing soft power Promote production facility sophistication investment
Representative new industry creation for a creative economy	Early visualization of smart convergence products Develop and commercialize 30 intelligent materials components Promote private sector R&D and investment
Smart innovation of local manufacturing	Activate the manufacturing business through a creative economy innovation center Realize smart locally based industrial complexes Promote locally specialized smart new industries
Business reorganization and innovation base creation	Promote spontaneous business reorganizations by the companies Improve regulatory systems for the convergence of new products Anticipatory training of the personnel to support manufacturing innovation

Figure 2.7: The major strategies and comprehensive assignments of Korea for the manufacturing innovation 3.0 (MOTIE, as of 2014)

Figure 2.8 shows manufacturing propulsion strategies and detail assignments proposed by Ministry of Trade, Industry and Economy (MOTIE) of South Korea. The primarily directions of the strategy include producing a new value added in manufacturing through IT&SW convergence, acquiring competitive advantage and establishing a suitable environment for companies to bring on new manufacturing innovation.

4 strategies	8 assignments
Create convergence of new manufacturing	Process innovation based on IT SW Create a convergence growth engine
Strengthen the key capabilities of the main industries	Enhance material and component Boost manufacturing soft power
Manufacturing innovation base enhancement	Supply customized personnel sites Leap to the Northeast R&D hub
Promote overseas expansion	Expand and utilize FTA Maximize summit diplomacy results

Figure 2.8: Smart Manufacturing propulsion strategies and assignments (MOTIE, as of 2014)

2.5 Industry 4.0 key technologies

Industry 4.0 is marked by highly developed automation and digitization processes and by the use of electronics and information technologies (IT) in manufacturing and services (Obitko & Jirkovský, 2015; Roblek, Meško & Krapež, 2016; Yuan, 2015). Real-time integrating and analyzing massive malicious data will optimize resources in the manufacturing process and will achieve better performance. Mobile computing, cloud computing, big data, and the IoT are the key technologies of Industry 4.0 (Gruber, 2013; Roblek, Meško & Krapež, 2016; Vijaykumar, Saravanakumar & Balamurugan, 2015; Wan et al., 2016).

As Industry 4.0 and Smart Manufacturing is a rather new concept that is still under development, many different opinions exist about what Industry 4.0 is and what is included in the concept due to the lack of a clear and generally accepted definition. Therefore, we selected several key and representative technologies for the enablers of Industry 4.0 and Smart Manufacturing, which are Internet of Things (IoT), Cyber-Physical Systems (CPS), Smart Factory and one principle that is the main outcome of this so called fourth revolution, Interoperability.

2.5.1 Internet of Things

The Internet of Things (IoT) is a convergence of smart devices that generate data through sensors to create new information and knowledge to boost human intelligence, efficacy and productivity to enhance the quality of life. IoT is defined as “Intelligent interactivity between human and things to exchange information and knowledge for new value creation”. It is a complex yet complete solution consists of three main technology components, namely connected things with embedded sensors, connectivity and infrastructure, and most importantly analytics and applications.

The term “Internet of Things” became popular in the first decade of the 21st century and can be considered an initiator of Industry 4.0 (Kagermann, Wahlster, Helbig, 2013). “Smart, connected products offer exponentially expanding opportunities for new functionality, far greater reliability, much higher product utilization, and capabilities that cut across and transcend traditional product boundaries” mentioned by Porter and Heppelmann (2014). Also Nolin and Olson (2016) note that the IoT “seems to envisage a society where all members have access to a full-fledged Internet environment populated by self-configuring, self-managing, smart technology anytime and anywhere”.

The innovation proposed by IoT is the ability to combine physical (eg. a window) and digital components (eg. a software) in order to create new ones (eg. a window that automatically closes the blinds when the sun hits that specific place during the day) the result of blending these two worlds are smart products (Wortmann & Flüchter, 2015). IoT is the foundation of smart infrastructures, for instance smart home, smart transport, smart cities, smart factories and so forth (Wang et al., 2016; Whitmore et al., 2014; Wortmann & Flüchter, 2015).

Smart factories are most of the time addressed through the umbrella concept of Industry 4.0. IoT used within smart factories and Industry 4.0 is often referred to as Industrial Internet of Things (IIoT) to make a distinction between the IoT used by consumers and the IoT used in smart factories (Albert, 2015). Within i4.0 IoT technology provides each product with a unique identifier and makes its data available in real time through the web, and the IoT offers product traceability throughout the entire product lifecycle (Whitmore et al., 2014) and enables flexibility and operational efficiencies, reshaping the supply chain and manufacturing process (Chung, 2015).

2.5.2 Cyber-Physical System (CPS)

Cyber-physical systems (CPS) are engineered systems that are built from and depend upon the seamless integration of software and physical components; CPS is characterized by a network of interacting elements with physical input and output, resembling the structure of a sensor network (Chang et al., 2015). Stanovich, Leonard, Sanjeev, Steurer, Roth, Jacson, Bruce (2013), addressed that a CPS often relies on sensors and actuators (or called actors, in some cases even called controllers as they control mechanisms or systems) to implement tight interactions between cyber and physical objects (Cited in Hu et al., 2016). The sensors (cyber objects) can be used to monitor the physical environments, and the actuators /controllers can be used to change the physical parameters (Hu et al., 2016).

In Industry 4.0 companies, CPS and humans are connected over the IoT and the IoS (Hermann et al., 2015). Cyber-Physical Production Systems consists of smart machines, warehousing systems and production facilities that have been developed digitally and benefit from end-to-end ICT-based integration, incorporating everything from inbound logistics to production, marketing, outbound logistics and service (Kagermann, 2015). In the area of manufacturing, CPS is a main technology for achieving Smart Manufacturing, and has close linkages with other key technologies such as IoT, cloud computing and big data.

CPS are defined as *"transformational technologies for managing interconnected systems between its physical assets and computational capabilities".* (Lee et al., 2015)

2.5.2.1 Cyber-Physical System architecture levels

Lee et al. (2015) summarized the 5C architecture for realizing CPS as (1) smart connection level, (2) data-to- information conversion level, (3) cyber level, (4) cognition level, and (5) configuration level. They also explained the detailed feature of conditions according to each level (Lee et al., 2015).

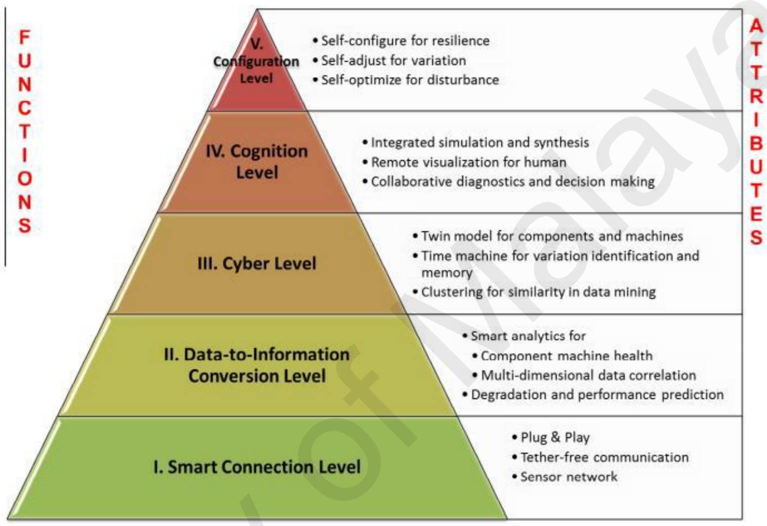

Figure 2.9: 5C structure for implementing CPS (Lee, J., Bagheri, B., & Kao, H.-A., 2015)

According to (Lee et al., 2015) in level I or Smart connection, precise and consistent data is generated by the different machines, components and controllers, and the different software used by the organization. Level II or Data-to-information conversion refers to the adaptation of data from one format to another keeping the integrity of the information during the process in order to foster the interoperability of the systems, this level brings up the self-awareness of the machines. Level III or cyber is the focal point of the information operations, here the whole information is gathered from the diverse machines, components, software and so forth, and analyzed and the self-comparison ability is constructed to allow machines to compare it with other machines or with historical figures. Level IV or cognition discusses the management of the information and knowledge generated in previous levels, now that the machine is self-aware and can compare it with others, therefore decisions regarding performance and maintenance can be constructed. Level V debates the response from cyberspace to physical space and provides machines with the ability of self-configure and adapt according to the needs of the production, here corrective and precautionary decisions can be made.

2.5.2.2 Automation

The definition of automation according to Frohm, Lindström, Stahre, & Winroth (2008), is usually related to the scale of machines' usage in manufacturing sites, but nowadays automation is grasping the use of different IT technologies in order to not only automate the physical work, but also to automate cognitive labor, the latter is the ability of systems and machines to generate, analyze, interpret data and decide the next step.

According to Frohm et al (2008) there are several ways to assess the Levels of Automation (LoA), however, most of these models assess automation in relation with human factors, for instance the degree of human intervention when operating a machine or the number of humans operating a production site. Furthermore, automation is not black or white, rather automation is continuous and varies in different points of time.

The basic level of automation is a human performing a manual job using only his or her hands and personal force, later a tool is provided to facilitate the work and therefore the technological level increase, subsequent the human and the tool are substituted by an automated machine to perform the same repetitive task. Every machine is automated with the use of subsystems that can be later fused together with the other autonomous machine to create networks of automated machines. Hence, they developed a 7-step reference scale model to describe and assess the level of automation in manufacturing sites (Figure 2.10). Frohm et al (2008) created a two-dimension model where they assess not only the type of equipment used by the production site, but also the degree of information sharing and analysis, these two dimensions are: Mechanical and Equipment and, Information and Control.

LoA	Mechanical and Equipment	Information and Control
1	**Totally manual** - *Totally manual work, no tools are used, only the users own muscle power. E.g. The users own muscle power*	**Totally manual** - *The user creates his/her own understanding for the situation, and develops his/her course of action based on his/her earlier experience and knowledge. E.g. The users earlier experience and knowledge*
2	**Static hand tool** - *Manual work with support of static tool. E.g. Screwdriver*	**Decision giving** - *The user gets information on what to do, or proposal on how the task can be achieved. E.g. Work order*
3	**Flexible hand tool** - *Manual work with support of flexible tool. E.g. Adjustable spanner*	**Teaching** - *The user gets instruction on how the task can be achieved. E.g. Checklists, manuals*
4	**Automated hand tool** - *Manual work with support of automated tool. E.g. Hydraulic bolt driver*	**Questioning** - *The technology question the execution, if the execution deviate from what the technology consider being suitable. E.g. Verification before action*
5	**Static machine/workstation** - *Automatic work by machine that is designed for a specific task. E.g. Lathe*	**Supervision** - *The technology calls for the users' attention, and direct it to the present task. E.g. Alarms*
6	**Flexible machine/workstation** - *Automatic work by machine that can be reconfigured for different tasks. E.g. CNC-machine*	**Intervene** - *The technology takes over and corrects the action, if the executions deviate from what the technology consider being suitable. E.g. Thermostat*
7	**Totally automatic** - *Totally automatic work, the machine solve all deviations or problems that occur by it self. E.g. Autonomous systems*	**Totally automatic** - *All information and control is handled by the technology. The user is never involved. E.g. Autonomous systems*

Figure 2.10: Levels of automation for computerized and mechanized tasks within manufacturing (Frohm, J., Lindstrom, V., Stahre J., & Winroth, M., 2008)

Mechanical and Equipment is the replacement of the human strength (level 1) for an entire operation of mechanized or automated machines (Level 7). On the other hand, Information and Control is the degree of interaction between humans and machines in a system in order to improve the understanding and awareness of the up-to-date and future situations, where level 1 is totally manual and the users employs their previous experiences to perform the task, and level 7 is totally automatic and information is managed by the IT system. (Frohm et al., 2008).

2.5.3 Smart Factory

With the development of new emerging technologies such as the Internet of Things and Cyber Physical Systems, the materialization of the Smart Factory (SF) is becoming a reality (Wang et al., 2016; Whitmore et al., 2014; Wortmann & Flüchter, 2015). Forstner & Dümmler (2014), argued that the Smart Factory is the key elements of Industry 4.0 as it provides a common ground for humans, machines and resources to communicate with each other, increasing the interoperability of processes enabling to change or adapt processes dynamics (Loos, Werth, Balzert, Burkhart, & Kämper, 2011).

Smart factories are vertically, horizontally and end-to-end engineered integrated to support the customization of products (Forstner & Dümmler, 2014; Wang et al., 2016). A Smart Factory is vertically integrated in the internal hierarchical subsystems of the operational processes creating an adaptable manufacturing system, it is horizontally integrated through inter-corporation value networks enabling collaboration from suppliers to customers and, it is end-to-end digital integrated with engineering crosswise the value chain to assistance product customization (Forstner & Dümmler, 2014; Wang et al., 2016).

The technical features demanded by the Smart Factory differ from the traditional factory (Figure 2.11). In traditional production lines the main objective is to produce high volumes of the same item, while in the Smart Factory the objective is to produce small-lots (also known as batch size one) of diverse types of a product, meaning that the sort of resources needed will increase. In Smart Factories the routing is dynamic and it is automatically reconfigured by the system with an ongoing production this is possible due to people, machines, resources and information systems are able to communicate with each other, in contrast the traditional production line is fixed and though reconfiguration is seldom required, it is done manually by people with the system down as the machines subsystems store information individually and it is not shared or interact with others.

In traditional production lines subsequent tasks depend entirely on previous workstations completed task, therefore the breakdown of a machine or workstation interrupts the production flow, whereas in Smart Factories the machines are aware of their condition and are able to decide to restructure the dynamic of the system. With Smart Factories, the information generated by one machine is storage and analyses in the Cyber-Physical System where it can be used by others, instead of been produced for the use of one user only.

Traditional production line	Smart Factory production system
Limited and predetermined resources – Mass production of one item	*Diverse resources* – Different sorts of a product that increases the number of resources
Fixed routing – the route is configured to follow same path and reconfigured manually with the system down	*Dynamic routing* – the route changes according to the different features of the product and it is done automatically
Shop floor control network – every machine performs a specific task and communication among them is not needed	*Comprehensive connections* – humans, machines, resources and information systems communicate with each other by means of a high speed network
Separated layer – machines are lonely subsystems and are separated from other information systems	*Deep convergance* – the industrial network is integrated by the Cyber-Physical System and IoT and IoS are created
Independent control – Every machine is configured to execute a task and malfuctioning of one affects the whole production line	*Self-organization* – the task is distributed to different entities and machines discuss and decide the dynamic of the system
Isolated information – the information generated by machines is normally used by the machine and rarely shared and used by others	*Big data* – Huge quantities of information are generated by systems and subsystems and it is stored and analyzed in the Cyber-Physical System

Figure 2.11: Smart factory production systems compared with traditional production lines (Wang, S., Wan, J., Li, D., & Zhang, C., 2016)

2.5.4 Interoperability

Interoperability is one of the main traits of Industry 4.0 (Hermann et al., 2015; Schuh et al., 2014), it is a key success factor to foster collaboration productivity through the different areas of companies and business partners (Daclin, 2012; Loos et al., 2011; Schuh et al., 2014). In contrast to Smart Factories that upholds the communication between machines, humans, systems and resources as a result of creating a Cyber-Physical System to gather and analyse information in order to decide the dynamic of the system (Wang et al., 2016), Interoperability under i4.0 is a fundamental factor at the supply chain level as it allows the collaboration between different organizations (Daclin, 2012; Loos et al., 2011). Daclin (2012), identified four required abilities of business partners for interoperability to function: partners must be compatible to ensure the right functioning of the system, interoperational ability to achieve high performance levels in relation to the quality of the exchange, the integrity of information and so forth, it ought to be autonomous and reversible as partners need to receive of provide services, resources, etc., keeping their own functions and objectives even if adjustments occurred.

The term of interoperability has two different approaches, the technological approach where interoperability is defined as "The ability of systems to exchange and make use of information in a straightforward and useful way; this is enhanced by the use of standards in communication and data format".(Daintith & Wright, 2008). This approach exposes the problematic that companies are facing when they try to connect with business partners as IT systems are written in different languages and therefore coupling them together is a difficult task (Daclin, 2012; Loos et al., 2011; Motiwalla & Thompson, 2012).

On the other hand, enterprise interoperability is "the ability of multiple firms to perform a generation of added value in division of labour, self-coordinated, within an overlapping business process, based on the exchange of coherent information, with a common goal and without fundamental changes to the initial organizational, procedural, and technical landscapes of the enterprises" (Loos et al., 2011). According to Loos et al. (2011), enterprise interoperability is built on three concepts: business, process and information interoperability. Business interoperability can be considered to be Industry 4.0 and according to Loos et al. (2011) this interoperability is determined by the market itself as this is going to define the drivers of the business and it is framed by the environment, for instance the culture, the regulations and the economy of the different markets.

CHAPTER 3: METHODOLOGY

Chapter 3 describes the methodology and method used so as to provide the scientific value of the given research. In this section we discuss and support our chosen research design, the reasons that motivated us to use an inductive approach with a qualitative research method by reviewing global trends of smart manufacturing technology, especially in developed countries and then conducting short questionnaire to relevant persons which focusing on key manufacturing sector.

3.1 Research design

3.1.1 Classification of research purpose

The research purpose of this study is to understand the concept of smart manufacturing and explore the feasibility of implementing it in Malaysia manufacturing companies by looking for patterns and ideas rather than testing or confirming hypotheses, therefore we assert that this work is completed as an exploratory research (Vogt, 2005).

Firstly, literature review was performed at the beginning of our research in order to demonstrate the scarcity of research done about implementation of smart manufacturing in other developed countries such as Germany, the US, Japan and Korea by identifying the policies and strategies established to enhance and support implementation of smart manufacturing in their respective countries. Furthermore, the policies and future plans of Malaysia government, which mainly from the Ministry of International Trade and Industry (MITI) and Malaysian Investment Development Authority (MIDA) also been reviewed. Through this study, the main technologies required to implement Smart Manufacturing were selected, and other related studies related were summarized.

Besides that, in this paper, one of our objectives is to understand the manufacturer's opinions on the potential challenges that they might face by embracing Industry 4.0 and Smart Manufacturing. Since current challenges and future expectations from Industry 4.0 have been limited information and lack of case data especially from manufacturing companies in Malaysia. Besides that, we also want to investigate the future scenarios from Industry 4.0 perspective and challenges related to them.

An exploratory research is challenging and special attention needs to be paid when writing a research of this kind as researchers often lose track, roam away from the purpose and end up in a totally different place (Stebbins, 2001), thereby we constantly review and remind ourselves of the purpose of this research in order to stay on the path of our study.

3.1.2 Research method

For our research in this paper, we used one of the qualitative techniques called case research strategy. As Industry 4.0 and Smart Manufacturing is relatively new research area, practice based problems, and poses new challenges, case research strategy is a best candidate (Eisenhardt et., all, 2007). Due to the novelty and complexity of this topic, the use of exploratory, qualitative case studies as a research strategy is recommended, as using a quantitative approach would make the research difficult or impossible to complete (Putney, 2010).

We are carrying out an exploratory research study as a result of the lack of previous researches and theories due to the novelty of this topic, limitation on acquiring proper information or data since there is not much study related to implementation of Industry 4.0 in Malaysia have been conducted so far. Presently, Ministry of International Trade and Industry (MITI) is leading a coordinated effort together with industry players, are in the midst of formulating the National Industry 4.0 Blueprint, which expected to be ready and tabled at the Cabinet by the end of this year.

3.1.3 Data collection

In this paper, one of our objectives is to understand the manufacturer's opinions on the potential challenges that they might face by embracing Industry 4.0 and Smart Manufacturing. Since current challenges and future expectations from Industry 4.0 have been limited information and lack of case data especially from manufacturing companies in Malaysia. Besides that, we also want to investigate the future scenarios from Industry 4.0 perspective and challenges related to them.

Hence, we prepared a questionnaire and distributed through online to relevant persons in key manufacturing sectors such as automotive, chemical, machineries & equipment, semiconductor, electric and electronic industries. Besides that, we also get insights from informal interviews during the IoT Malaysia seminar and review talks with government agency and industry specialist regarding current challenges in manufacturing environment. Furthermore, the data also been supported by reviewing reliable news, article from several local industry big players, manufacturer's organization, economic research analyst and industrial expert's opinions related to Industry 4.0 in Malaysia.

3.2 Sampling

We had a specific target of what characteristics we wanted our respondents to have and created a list where we specified the criteria regarding the company size, industry and position in the supply chain, as well as the positions of the respondents. The criteria we used were following:

- Manufacturing industry: Focus on key manufacturing sector such as automotive, chemical, machineries & equipment, industrial manufacturing, semiconductor, electric and electronic industries.

  Motivation: Focus on target industries which have been identified to drive the growth of the manufacturing sector.
- Background of company: Either Malaysia firm or foreign firm without localized manufacturing or foreign firm with localized manufacturing (i.e. its own production capacity and/or contract manufacturing)

  Motivation: Open for all manufacturing firms either local or foreign-owned firm which based in Malaysia.
- Size of company: Small (less than 100 employees), Medium (100-500) and Large (1000 employees and more).

  Motivation: Targeted a larger firm which likely to have a more advanced production process, and at least somewhat familiar with more advanced technology so that they are not doing everything manually since the question about the feasibility then would be completely unnecessary then.

- Respondent’s position: Targeted working level position such as technician, engineer and management level position starting from manager until high level management personnel such as General Manager, Head of Production, CEO, CFO and others.

  Motivation: The CEO or high level management personnel will have a more holistic and probably have better oriented perspective of the company’s direction and its business, as well as being responsible for the strategic decisions which hence gives a very valuable insight and point of view. The head of production or general manager might be able to provide another angle as being the one who is more involved in the production process and having the detailed knowledge about the current operations, types of machines, efficiency within production, idle time at the different work stations etc. Meanwhile, working level position might have profound knowledge of advanced production process and their respective work scope.

CHAPTER 4: RESULTS AND DISCUSSION

This chapter represents the survey findings based on the material collected from short questionnaire and informal interviews, where we show the main results of this research, followed by the analysis where we apply the theory of Industry 4.0, presented in the framework, to the findings of our research in order to identify the challenges, benefits and trade-offs with by implementation of Industry 4.0 to manufacturing companies in Malaysia.

4.1 Implementation of smart manufacturing in developed countries

4.1.1 Key strategies to support implementation of smart manufacturing

The first part of the paper was focused to the basic foundation of Industry 4.0 and to investigate the implementation of Smart Manufacturing in developed countries such as German, US, Japan and South Korea by reviewing key strategies or policies established to enhance and support implementation of smart manufacturing in their respective countries. A brief literature review indicated that there is no generally agreed-upon definition and understanding of the approach yet.

As discussed in the previous chapter, the Industry 4.0-related study of Germany, Smart Manufacturing-related research of the U.S, and the strategies established from 'Japan Revitalization Strategy 2016' and 'Manufacturing Industry Innovation 3.0' of Korea were investigated to select key technologies. In the German case, it's been mentioned that IoT, IoS, and CPS must set up first to integrate these existing complex systems, and other various key technologies such as big data, sensors and cloud computing. Meanwhile, in the US, the government concentrates on research and development projects related to the key technology task, including CPS, IoT, big data analytics, cloud computing, sensor and additive manufacturing. In the case of Korea, the core technologies selected for implementation of Smart Manufacturing include IoT, CPS, cloud computing (cloud manufacturing), big data, additive manufacturing (3D printing), sensors, energy saving and holograms.

Meanwhile, in Malaysia, Industry 4.0 and Smart Manufacturing details action plan or strategic roadmap has not been established yet. However, the Government has initiated Industry 4.0 Task Force comprising key ministries and agencies in order to oversee specific proposals based on five elements, namely infrastructure and ecosystem (Communications and Multimedia Ministry), funding and incentive (Finance Ministry), talent and human capital development (Higher Education and Human Resources Ministries), technology and standards (Science, Technology and Innovation Ministry), and small and medium-sized enterprises development and Industry 4.0 (International Trade and Industry Ministry).

Meanwhile, National Internet of Things (IoT) strategic roadmap has been established by the Minister of Science, Technology and Innovation (MOSTI) in 2015. A key objective of the roadmap was to create a national IoT ecosystem to enable the proliferation of use and industrialization of IoT as a new source of economic growth. To move forward, MITI in collaboration with other ministries is formulating the National Industry 4.0 Blueprint, which expected to be ready by the first quarter of next year.

Meanwhile, the Malaysian government has proposed various incentives in order to encourage the private sector to implement Smart Manufacturing and enhance more value-add activities in the manufacturing sector. In Budget 2018, the government embarks of the basic, yet fundamental, foundations for Malaysia’s evolution towards Industry 4.0. For example, to support and encourage early adoption of Industry 4.0 and automation by businesses, the Government has proposed various tax incentives, including the extension of the 100% Accelerated Capital Allowance (ACA) and 100%

Automation Equipment Allowance (AEA), which were previously introduced to encourage automation in the manufacturing industry.

In addition to that, Malaysia government has established new tax incentives especially for transformation to Industry 4.0. It is proposed that Accelerated Capital Allowance (ACA) and Automation Equipment Allowance (AEA) will be granted on the first RM 10 million qualifying capital expenditure incurred by companies in the adoption of the technology drivers (big data analytics; autonomous robots; industrial internet of things; cloud computing; additive manufacturing and others). Furthermore, in the Budget 2018 announcement, the government has allocated RM245 million grant under the Domestic Investment Strategic Fund in order to encourage the manufacturers to upgrade their facilities for Smart Manufacturing. This incentive is in line with the industry's aspirations to fully automate and modernize its manufacturing plants across the country.

4.1.2 Key technology areas that are focused on smart manufacturing.

As reviewed in the previous chapter, Germany, U.S., Japan and Korea are executing various projects related to Industry 4.0 and Smart Manufacturing. Those countries selected their core technology areas to focus and they are the main players in technology development. Through this study, the core technologies required to implement Smart Manufacturing were identified and the common core technologies of the three countries were selected as summarized in Table 4-1, as one of the objectives of this paper is to analyze key technology areas that focus on Smart Manufacturing.

Table 4-1: Classification and selection of core technology for smart manufacturing

Germany	**USA**	**South Korea**	**Malaysia**
CPS	CPS	CPS	CPS
IoT	IoT / Wireless Platform	IoT	IoT
IoS	Big Data / Data Analytics	Big Data	Big Data / Data Analytics
Big Data	Cloud computing	Cloud computing	Cloud computing
Cloud computing	Sensor	Sensor	Sensor
Smart Energy	Smart Energy	Smart Energy	Smart Energy
Sensor	Additive Manufacturing	Additive Manufacturing (3D Printing)	Additive Manufacturing (3D Printing)
		Hologram	

As for Germany and the US, the core technologies with similar concept were selected even though they were not expressed in the same words. The core technologies suggested for implementation of Smart Manufacturing in Malaysia include CPS, IoT, cloud computing (cloud manufacturing), big data, additive manufacturing (3D printing), sensors and Smart Energy.

4.2 Feasibility of implementing Industry 4.0 in manufacturing in Malaysia

Table 4-2: Summary of respondent's information

Type of manufacturing firm	Local / foreign firm without localized manufacturing or foreign firm with localized manufacturing	Size of the company	Position (No.)	Total Respondent No.
Electric, electronic & semiconductor	Foreign firm with localized manufacturing	Large (1000 employees and more)	Engineer (6) Technician (1)	7
Industrial manufacturing	Foreign firm with localized manufacturing	Medium (500-1000 employees)	Engineer (7)	7
Chemicals	Foreign firm with localized manufacturing	Large (1000 employees and more)	Engineer (3) Procurement (1) Technician (1)	5
Machinery & Equipment	Foreign firm without localized manufacturing	Medium (500-1000 employees)	Engineer (3) Manager (1)	4
Metal and Metal products Manufacturing	Malaysian firm and Foreign firm with localized manufacturing	Medium (500-1000 employees)	Engineer (3)	3
Automotive	Malaysian firm	Large (1000 employees and more)	Engineer (2) Technician (1)	3
Others : (Medical device, ICT)	Malaysia firm	Small (less than 100 employees)	Engineer (2)	2
Total respondents				31

Based on the summary table as above, we have received 31 respondents which belong to diverse industry segments from electric and electronic industries (22.6%), industrial manufacturing (22.6%), chemical (16.1%), machineries & equipment (12.9%), automotive (9.7%), metal related products manufacturing (9.7%) and other industries (6.4%). Among all respondents, about 56.7% are working with foreign firms with localized manufacturing, 30% working for Malaysian firm and remaining 13.3% are foreign firm without localized manufacturing. Moreover, 61.3% respondents claimed that they were working in a large organization, 25.8% respondents working at medium firm and the remaining 12.9% respondents working with small firms. From the table 4.2, it can be seen that the majority of respondents was working level position; engineer (83.9%), technician (9.7%), procurement (3.2%) and manager (3.2%).

4.2.1 Current status implementation of Smart Manufacturing system

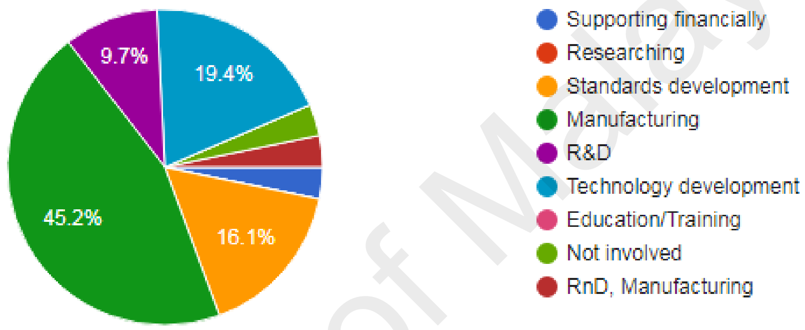

Figure 4.1: Current status implementation of Smart Manufacturing system

Surprisingly, our survey shows that 45.2% of respondents have started adopting Smart Manufacturing system in their respective manufacturing companies. Meanwhile, 19.4% of respondents indicate that they were undertaking technology development phase and a further 16.1 % of respondents claimed that they were undertaking standard development phase. 9.7% of respondents said that it still in research and development and the remaining 9.6% of respondents said they have not yet involved in smart manufacturing (See figure 4.1).

Most of the respondents which mentioned they are actively involved in Smart Manufacturing are mainly come from large foreign firm with localized manufacturing especially in electric, electronic and high tech industries, chemical, automotive and industrial manufacturing (rubber and plastic goods) industries. Meanwhile, respondents from small companies which responses in the survey indicate that they have not yet involve in smart manufacturing system. Based on the survey results, large companies substantially more advance in the integration of their production plants in higher-level IT systems than medium-sized companies and the latter are much more advanced than small companies.

This survey finding is in line with the report established by MITI, which indicated that the majority of foreign multinational companies (MNCs) in Malaysia has embraced the technological revolution of Industry 4.0. Several global MNC players which has been started to adopt Industry 4.0 concepts of smart factory, data analytics and automation in Malaysia such as Intel Corp, Osram Licht AG, B Braun Melsungen AG, Robert Bosch GmbH, Agilent Technologies Inc, Jabil Inc, Dell Inc, Infineon Technologies, Muehlbauer and others. In addition, leading multinational E&E company, Infineon Technologies recently have launched of Block 8 in Melaka, which the infrastructure is designed for a more automated, connected and controlled manufacturing environment to support Industry 4.0 operations that will help to increase efficiency of their equipment, material, processes and workforce.

Furthermore, according to MIDA report, some of the Malaysian companies are already undertaking research and development and system integration as well as developing appropriate machinery and equipment for global exports. Up to now, there are 165 projects has been approved to manufacture robotics and automation equipment for various industries (MIDA, 2017). Most of them are in specialized machinery and equipment for the semiconductor industry and material handling. Besides that, there are many established local system integrators (SI) such as ACM, ViTrox, VisDynamics, Kobay Technology, Genetec, Greatech, RC Precision, Pentamaster and others which can provide integrated automated solutions for high tech industries.

Besides that, based on The Edge, Penang Special Report, ViTrox Corp Bhd, Pentamaster Corp Bhd and Walta Engineering Sdn Bhd are setting up a one-stop metal component supply chain hub featuring 18 SMEs that will cater for Penang-based MNCs and LLCs in order to prepare SMEs for the transition towards Industry 4.0. The hub, called Penang Automation Cluster (PAC) is the first SME precision metal fabrication or an automation, cluster in Malaysia that will support and enhance the development of the existing supply chain ecosystem of industries which are primarily in the semiconductor, E&E and medical device segments.

Furthermore, we also requested the respondents about their interest in exploring accessible Smart Manufacturing system to their manufacturing companies. 48.4% of respondents mentioned that they are interested to apply smart manufacturing system in integrated across all levels. Meanwhile, 19.4% of respondents indicate their interest to apply smart manufacturing at machine level, 16.1% of respondents said their interest to apply smart manufacturing at plant level and remaining 12.9% interested to apply in supply chain levels (See figure 4.2).

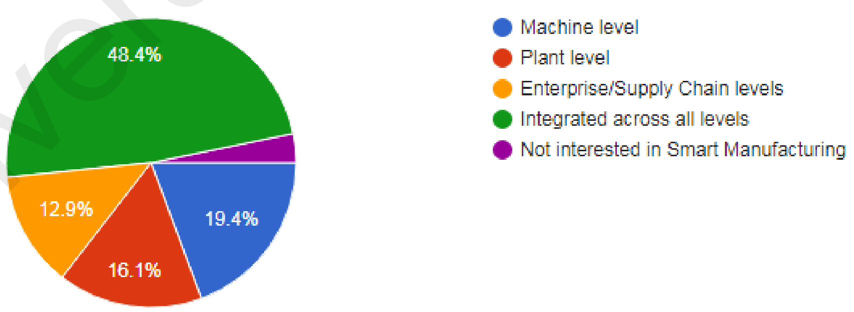

Figure 4.2: Level of interest to adopt Smart Manufacturing system

Based on the survey findings and informal interviews during IoT seminar, it gave indication that the transformation towards Smart Manufacturing for large multinational manufacturing firms in Malaysia is making partial progress. In contrast, local small and medium enterprises (SMEs) are still in the infancy stage in terms of automation and slow on the uptake for this new transformation. Since these transformations will not only impacting companies' competitiveness and provide new opportunities, it is also affecting other issues and challenges.

The implementation of the smart manufacturing will affect totally new type of challenge for manufacturing industry and will play a significant role in terms of competitiveness. The majority of the respondents surveyed emphasize that the transformation towards Industry 4.0 could enhance Malaysia industry global competitiveness (See figure 4.3): 48.4% of respondents fully agreed and further 48.4% agreed that this was the case.

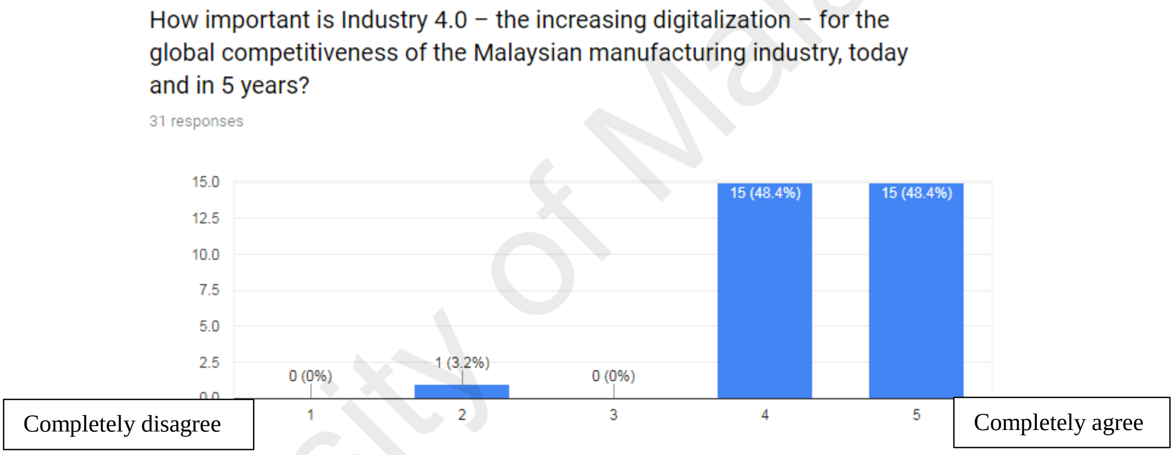

Figure 4.3: Industry 4.0 potential for increasing competitiveness of Malaysia manufacturing industry

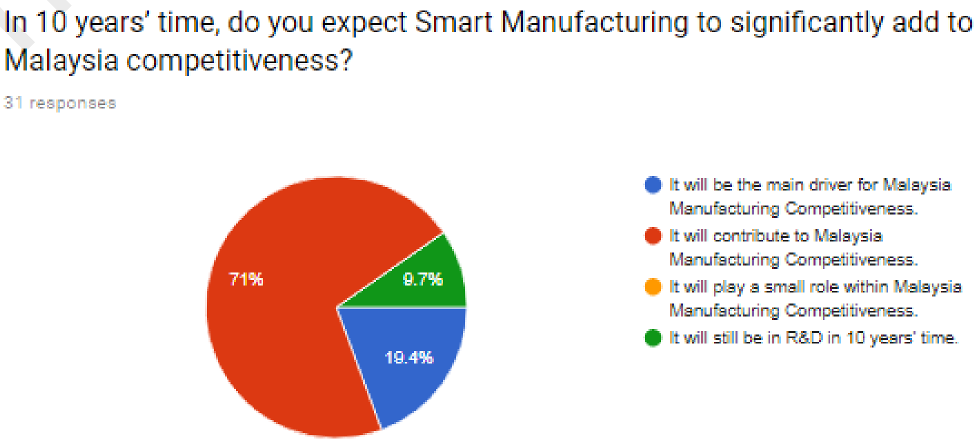

Figure 4.4: Smart Manufacturing increase competitiveness in future

Furthermore, when asked about the importance of Industry 4.0 or whether smart manufacturing will significantly contribute to Malaysia competitiveness, majority of key players in manufacturing industry emphasized that the significant importance of embracing Industry 4.0 and indicated that it would become much more important in future. Based on above figure 4.4, 71% of respondents believed that Smart Manufacturing will significantly contribute to Malaysia manufacturing competitiveness in next 10 years' time. Meanwhile, 19.4% of respondents expect that smart manufacturing will be the main driver for Malaysia manufacturing competitiveness. Only 9.7% believe that it still be in research and development in 10 years' time (See figure 4.4).

In summary, large multinational manufacturing firms already recognize the transformation towards Smart Manufacturing is very crucial. By contrast, small and medium-sized companies still not realize Smart Manufacturing will be great importance to them, even though the companies are most likely to have significant benefits from the transformation. Moreover, based on the survey results, the transformation towards Industry 4.0 has equivalent importance in every sector. Manufacturing companies especially from electric, electronic and high tech industry, chemical, automotive, mechanical and equipment and other industrial manufacturing such as rubber and plastic goods industry foresee it have tremendous potential. Meanwhile, small companies in the certain areas such as metal and metal products manufacturing are currently considering it as least important to them. However, we can conclude that most respondents from the diverse manufacturing industry in Malaysia surveyed agree that Industry 4.0 has a lot of potential to increase Malaysia manufacturing competitiveness.

4.2.2 Potential barriers and challenges to implementation of Industry 4.0

To find-out, what the major challenges manufacturing industry might face, we prepared a short questionnaire and distributed it through online to relevant persons in targeted industries. We also include the feedback from informal interviews during the IoT Malaysia 2017 seminar and reviewing reliable news, article and talks from several local industry big players, manufacturer's organization, economic research analyst, industry experts and consultants which involved in a manufacturing environment. These manufacturing companies belong to various industry segments. Although due to numerous industry segment and complex nature of their businesses, challenges are also varied, but there are also some common challenges. From our results, we discuss top four challenges out of eight, in this paper due to limited time.

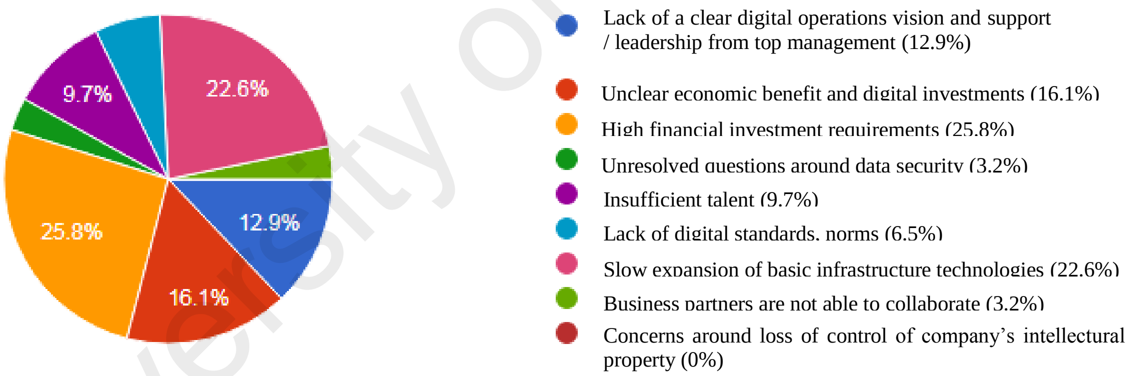

Figure 4.5: The major challenges in order successfully to adopt Industry 4.0

The major challenge in successfully implementing Industry 4.0 and Smart Manufacturing is that the high investment requirement and unclear economic benefits. Near half of total respondents (41.9%) emphasize this aspect. Other potential challenges include the workers lacking sufficient qualifications and slow expansion of basic IT infrastructure and stable networks. A fourth challenge is that the technology used is not enough developed and other possible barriers might be lack of support from top management (See figure 4.5).

Meanwhile, the respondents consider least challenges in terms of data security and digital standards and norms. In summary, the potential challenges manufacturing firms might encounter for implementation of Smart Manufacturing and Industry 4.0, can be divided into four categories; financing, competencies, administration and technology.

4.2.2.1 High financial investment and unclear economic benefits

The development and adoption of Smart Manufacturing's technologies may require significant investment. The majority of the manufacturing companies surveyed agree that high financial investment and unclear economic benefits will be the major challenges in successfully introducing Industry 4.0 (See figure 4.6): 25.8% of respondents firmly agreed and further 74.2% agreed that this was the case.

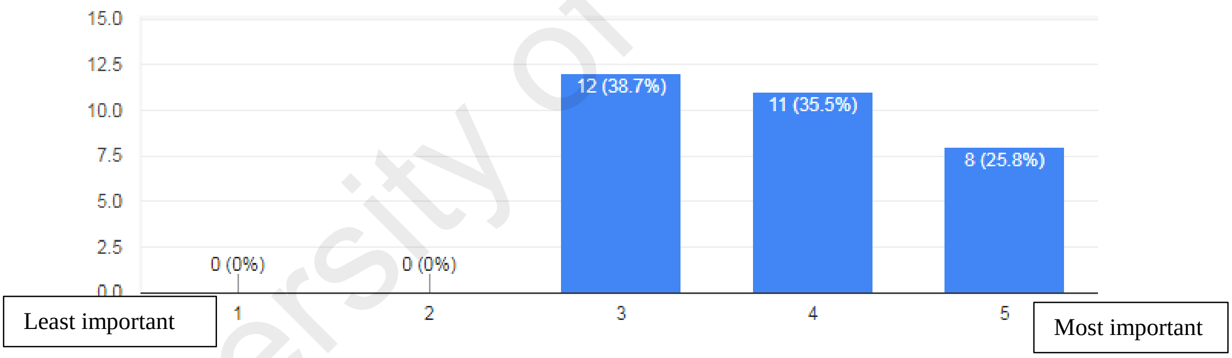

Figure 4.6: High financial investment and unclear economic benefits is the greatest challenges facing companies

Based on PwC's 2016 Global Industry 4.0 Survey, it suggests that global industrial products companies will invest US$907 billion per year through to 2020. The major focus of this investment will be on digital technologies like sensors or connectivity devices, as well as on software and applications like manufacturing execution systems (MES). In addition, companies are also required to invest in training employees and driving organizational change.

Based on studies on Malaysia’s automation investment, only 30% of manufacturers have considered investing and leveraging this cutting-edge technology despite being initially positive on the concept of industry 4.0. There are a lot of factors have influenced their decision to invest in this new IT technology such as shortage of skilled workers, high production costs as well as current weak economic climate. Furthermore, another surveyed indicate that almost 40% to 50% of existing factory’s equipment might need to be upgraded or replaced in order to operate the new integrated smart manufacturing (MPC, 2017). Thus, it shall take significant investment for a number of years to fully adjust existing factories to future smart manufacturing requirements.

In summary, lack of financing could be a major challenge for many businesses, especially SMEs, to adopt Industry 4.0. However, a start has to be made especially in the mindset switch of SMEs towards greater acceptance of Industry 4.0. In today's manufacturing environment, local SMEs cannot heavily rely on foreign labor anymore, but need to consider changing their business processes via the adoption of new modern technologies such as robotics, Cyber Physical System, cloud manufacturing and artificial intelligence. Recognizing the importance of financing, the Government has announced in Budget 2018 to allocate RM245mil under the existing Domestic Investment Strategic Fund (DISF), where eligible businesses will be able to apply for a matching grant to upgrade to Smart Manufacturing facilities.

4.2.2.2 Slow expansion of basic infrastructure

Fast, secure and stable data connections is a key condition for the implementation of Industry 4.0. Based on International Telecommunication Unit (ITU) standard, it indicates that the companies have to achieve a transfer rate of at least 2 Mbit per second (Mbps) as a basic internet connection. However, in international comparison level, Malaysia’s broadband provision is still in the mid-range. As of first quarter 2017, Malaysia's average internet connection speed (IPv4) is 8.9 Mbps. Based on 2017 State of the Internet Report (Soti), Malaysia is ranked 62th place worldwide and lag far behind with other developed countries who likely to implement Industry 4.0 such as South Korea (28.6 Mbps), Singapore (20.3 Mbps) and Japan (20.2 Mbps).

Due to this mid-range of connection rate, it suggests that current Malaysia's basic IT infrastructure is not at the level to fully capable to support the digital transformation toward Industry 4.0. Most companies especially in rural areas would be struggle for establishing inter-company internet-based production and other services, such as transferring real-time big data. Only stable and high-speed internet connection via fiber optic cable is capable of that. This is supported by our result's finding which show that only 46.7% of respondents mentioned that their company has the appropriate IT infrastructure in place that could convergence data to support the implementation of Industry 4.0. Meanwhile, 46.7% of the survey results show that they partially have some of the basic IT infrastructure in place, while the remaining 6.7% of respondents mentioned that they lacked any appropriate infrastructure.

Moreover, Industry 4.0 requires existing IT infrastructure need to be adjusted and in some other cases, wholly new types of systems need to be established. However, the cost implications will be a crucial factor for all manufacturing companies when making decisions whether to upgrade existing IT infrastructure or to develop new systems. Besides that, the need to upgrade fiber optic coverage in a short period in order to implement Smart Manufacturing is correspondingly great. There is no other option besides to expand fiber optic coverage, given the level of this modern technology. Else, the feasibility to implement smart factories would be impossible. Therefore, many Malaysia manufacturing companies still have a lot of work to do especially to upgrade their existing IT infrastructure in order to fully adopting Industry 4.0 technologies.

4.2.2.3 Insufficient talent

Talent is the other major challenge. The success of Industry 4.0 is highly dependent on the capability of the workforce to innovate and apply advanced knowledge and technologies. For the development and utilization of Industry 4.0, a qualified workforce is very crucial. Different skills will be needed to operate the systems of the smart factory in order to fully implement Industry 4.0.

The talent capabilities and number of skilled workforces that Malaysia manufacturing industry will require to implement Industry 4.0 still remains unclear. The main factor in this issue will be the uncertainty of the areas where staff is needed and the actual numbers required. Just 16.1% of respondents surveyed mentioned that they already had enough skilled workers they needed, while 71% said they only had the skills in certain areas. The remaining 12.9% said they completely lacked of the necessary skills. This finding indicates that the problem in the future for Malaysia is not lack of employment, but the shortage of skills that the new jobs will demand.

To implement Industry 4.0, crucial role need to be taken by university, industrial associates and skills development organizations in supporting the manufacturing sector by providing sufficient and well-qualified workforce needed. For instance, Penang Skills Development Centre (PSDC) has provided a prominent role by continuously keeping a close relationship with the industries and provide relevant industrial machinery to contribute to skills formation. The smart collaboration between the PSDC and Penang based MNC corporations, universities and other relevant government agencies have resulted in a more relevant curriculum to industrial needs being created. This partnership between PSDC and other organization indeed provides room for co-resources finding to design, plan, and conduct training programs in a wide range.

The crucial determinant for an innovative economy strongly lies in the availability of human resources. In terms of the number of scientists and engineers in R&D and researchers, Malaysia is lagging far behind compared to Singapore, China and Korea. Currently, the technical knowledge required for each of these phases is still lower than its primary target in Malaysia, recruited primarily from the so-called Science, Technology, Engineering and Mathematics (STEM) subjects. The number of graduates in STEM subjects has fallen short of demand for some years. This development has led to a shortage of skilled workers in important positions for the implementation of Industry 4.0, such as electrical engineering, informatics and software development.

The transformation toward Industry 4.0 comes with new challenges for the majority of employees. Existing automated process-dependent systems which been a convergence with latest cutting-edge technology might be the major challenge for existing employees. In some cases, employees require extensive training to operate these new applications and make full use of them. Hence, in the next few years Malaysia manufacturing companies will need to pay significant attention to flourish their worker competencies in order to establish digitally sophisticated workforce for this digital transformation.

4.2.2.4 Lack of core technology

Research and development (R&D) are a key success factor for Industry 4.0. The importance of research, development and innovation activities has received strong attention due to the increasingly competitive manufacturing environment. This is not only applicable for R&D for new products, but also the capability to utilize this modern technology in order to further develop and enhance innovation in manufacturing products and processes.

It is found that Malaysia is still largely dependent on foreign technology despite been successfully ranked among top exporters of high technology products (43.87% of Malaysia's export in 2016 is in high technology industries). Malaysia mostly learned from more advanced countries in using imported new technology and equipment. Major challenges including country's weak position in terms of research & development and innovative capability have been identified. However, it is the golden time to upgrade the Malaysia industry from the assembly stage of manufacturing, design and development of new products. In fact, the overall concept of Industry 4.0 is premised on innovation and development. Let's consider the R&D spending to GDP statistics by some of the early adopters of automation and Industry 4.0:

Country	2015	2016
Germany	2.89	2.88
Japan	3.40	3.28
United States	2.75	2.79
Malaysia	1.26	1.30
China	2.02	2.07

Source: The World Bank, Research and development expenditure (% of GDP)

Figure 4.7: Research and development expenditure (% of GDP) (World Bank, 2016)

The first few countries that initiated Industry 4.0 were Germany and the United States. These countries recorded a significant level of R&D spending as a percentage of their GDP. Comparing the R&D expenditure (Figure 4.7) it is clear that Malaysia is still lagging behind from many other developed nations such as Japan, Korea, Singapore and China since Malaysia has only recorded 1.30% in 2016. If Malaysia were to successfully move to Industry 4.0, it will need to consider measures to further assist and encourage R&D spending.

Therefore, the government would need to put emphasis on developing the national system of innovation and provide more proactive R&D infrastructure to be able to develop its own core technologies. Under 11th Malaysia Plan 2016-2020 (11th MP), the government continues to focus on R&D activities. This is indeed in line with the National Science, Technology and Innovation Policy aim for Malaysia to achieve Gross Expenditure on R&D (GERD) of at least 2.0 percent by 2020.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

This chapter concludes and summarized the overall results, which also answers our research question of the feasibility of implementation i4.0 for manufacturing companies in Malaysia, based on the benefits, trade-offs and barriers presented in the analysis and we then finish off with suggestions for future research.

5.1 Conclusion

In this paper, we mentioned that there is no commonly agreed-upon definition and understanding of the Industry 4.0 concept. In summary, this new industrial revolution can be expressed as a transformation from existing assembly and device-oriented industry towards the innovation of leading a new convergence industry, enabled by latest cutting-edge IT technologies such as Internet of Things, Cyber Physical System, Smart Factory, Cloud Manufacturing, Big Data and additive manufacturing, hence as to help manufacturers to prepare for future manufacturing demands.

Many of the manufacturing firm especially big multinational companies (MNC) in Malaysia are working towards Industry 4.0 in a certain way without knowing it as they are all trying to increase the interoperability of their systems and subsystems. In this sense, we agree with Albert (2015) and Kagermann (2015) that the future implementation of Industry 4.0 not is likely to be a revolution, but rather an evolution. The capability of organizations to fully utilize the benefits of Industry 4.0 depends on several factors that are not always related to the level of automation or technological features, instead the business strategy and culture, as well as the managements' mind-set play a vital role when it comes to adapting to an external change.

In regards to the feasibility of implementation Smart Manufacturing in Malaysia, the results show that the concept of Industry 4.0 as a comprehensive solution is only feasible for large and medium-capacity firms rather than SMEs. It would be a tough challenge to implement Smart Manufacturing especially for local SMEs, which accounted 95.4 per cent of companies in the manufacturing sector due to economic factors as well as the nature of the business. Instead, the adoption of Industry 4.0 will majorly depend on company size. Since the level of dissemination among large companies is higher; therefore they are expected to easily implement the relevant Industry 4.0 technologies rather than SMEs. Moreover, large companies relatively more advance in the integration of their production plants in higher-level IT systems than SMEs.

Many challenges lie ahead in the march towards the Industry 4.0 adoption. Based on the research findings, one of the major challenges in successfully introducing Industry 4.0 is that the large investments required are perceived to have unclear economic benefits. Other potential barriers include the employees lacking adequate qualifications and slow expansion of broadband and stable networks. Another challenge is that the technology used is not sufficiently developed, and another hinder may be the fact that the issue of digitization is not a top priority with higher management. Besides that, there is also an indication that the current scenario of Malaysia's manufacturing sector actually looking for greater automation before players can fully embark on Industry 4.0.

Despite the consistent initiative from the government to encourage manufacturing companies especially SMEs to implement Industry 4.0 and Smart Manufacturing, there are still many issues to be considered in terms of basic infrastructure's readiness, sufficient talent capabilities, research and development of core technology. Hence, the transformation will require full commitment and concerted efforts from all relevant parties including manufacturing companies, governments, universities, skills and training development center and other stakeholders in several areas in order to prepare Malaysia to embrace on future smart manufacturing application. The readiness and ability of the Malaysia to introduce Industry 4.0 also depends on the framework conditions. The financial environment, the availability of skilled workers, extensive and high-performance broadband access, government support and legal framework conditions are all key factors here.

Malaysia is poised to remain competitive by embracing smart manufacturing and robotics and automation, and adopting high-technology production value chains. With the establishment of Industry 4.0 details action plan and strategic roadmap as well as extensive collaboration between industries, government and other relevant parties, Malaysia is on the right track to be integrated into the high-technology global supply chain.

5.2 Recommendation

What we found in this study is only an indication of what might apply to Malaysia manufacturing companies, based on the findings from our research of these companies; hence our conclusions cannot be generalized to all Malaysia manufacturing companies which include SMEs. Further research can be done to validate the conclusion that Malaysia manufacturing companies including SMEs not are likely to implement Industry 4.0 as it is defined today, but rather to create different applications for the usage of these technologies. We suggest that a quantitative study can be done to substantiate these conclusions.

In order to gain more representative and objective results, a larger base of interviews or round table discussion that may involve industry specialist, policy makers or top level decision makers who have a more holistic and probably have better oriented perspective of the company's direction would have been suggested. Besides that, an "Industry 4.0 Readiness Framework" analysis should be another option in order to review the potential challenges for implementation of Industry 4.0 by analyzing much more details factors such as availability of technology, degree of digitization, workforce capabilities and education.

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