Identifying Factors Contributing to the Level of Industry 4.0 Technologies Adoption among SMEs in Different Countries

Nurul Izzati Naqibah Zaidi, Mohamed Saleem Nazmudeen, and Fadzliwati Mohiddin

***Abstract*—Industry Revolution (IR) 4.0 technologies are considered crucial in industries to gain competitive advantage and optimize their performance. This study aims to compare different levels of adoption of IR 4.0 technologies from various industries in developed and developing countries. The comparison of countries on IR 4.0 technologies adoption from basic to advanced levels are shown in this research paper using our unique simplistic approach. Also, we identify what are the contributing factors that affect the level of adoption of these technologies. It has been concluded that developed countries are slightly higher in adopting technologies compared to developing countries. Research conducted is qualitative and descriptive, using secondary data from eight different countries from developing and developed categories.**

***Index Terms*—Digitalization, IR 4.0, Maturity models, SMEs, Technology adoption.**

I. Introduction

Global industries are facing another phase of revolution in recent years as technologies are rapidly advancing giving more opportunities for value-creation irrespective of small, medium or large enterprises. The term digitalization has been spreading across the globe giving a strong impact on the usage of technologies especially for large manufacturing countries such as Germany or Japan and became a role model for other countries to follow their steps to revolutionize. Technologies these days play an important role in any business from simple basic e-mail to heavy autonomous robots, these technologies are aiding businesses for faster decision-making and increase flows of efficiency. This qualitative and descriptive study will extensively quote the previous recent literature on the topic. Different case studies have been gathered from the research journals, comparing eight different countries from developing and developed categories. This paper presents a simple and comprehensive maturity model with technologies that are frequently implemented in Small, Medium Enterprises (SMEs). The research sample in this paper is limited to a few specific countries with various levels of adoption of technologies for the Fourth Industrial Revolution.

To categorize countries for this research study, we refer to the United Nations report. This report is updated and published recently in 2019. Below are lists of developed and developing countries illustrated in Table I. The reasons for choosing the above countries are to differentiate how each categories. Some developed countries might use advanced country is using technologies despite coming from the same technologies but do not focus on medium level technologies such as social media or online platform because of the nature of the complicated and advanced manufacturing industry, for example, assembly line and heavy machinery manufacturing but not using medium technologies such as social media or big data. Some countries in developing categories might start to implement a different type of technologies from basic to advance although they are still in the developing phase compared to other developed countries, for example manufacturing business that still uses an online platform to export and reach the international market.

TABLE I: Lists of Developed and Developing Countries from UNN Report

No.	Categories	Countries
1	Developed	Germany
2	Developed	Sweden
3	Developed	South Korea
4	Developed	New Zealand
5	Developing	Brazil
6	Developing	Malaysia
7	Developing	Indonesia
8	Developing	Taiwan

II. Related Work

A. Industrial Revolution

Before the Fourth Industrial Revolution begins, there were different phases of industrialization happening from the year early 1800 until the late 1900. First Industrial Revolution was when manual and traditional handcrafting are improved by machines powered by steam and coal. The First Industrial Revolution was in Britain in 1800 where industrial production was by using traditional machines in factories especially in textiles and clothing, iron and other area compared to previous traditional hand-working production methods [1]. A few centuries back according to Xu, David and Kim in 1760, the first industrial revolution started with steam power and coal for industrialized manufacturing process and transportation [2]. The Second Industrial Revolution was in the 1900s with using oil and electricity for mass production. The Second Industrial Revolution was when machinery was powered by electricity and oil and Third Industrial Revolution was the beginning of industries using electronics and information system where computers are integrated with machines.

The third industrial revolution started in 1960 using

Manuscript received May 11, 2022; revised July 14, 2022.

The authors are with University Technology Brunei, Brunei (e-mail: P20191008@student.utb.edu.bn, mohamed.saleem@utb.edu.bn, fadzliwati.mohiddin@utb.edu.bn).

electricity and information technology for production which was the rise of electronics as well [3]. According to Caputo *et al.*, 2016 as cited by Agostini and Nocella, the source of the third industrial revolution was from the advanced stage of info-tech, computerized manufacturing and electronics as well as digitalization which increase output, monitorization and production. After the third phase of industrialization integrated system, machines have been widely implemented, the availability of internet network stepped up the industrial game by integrating systems of machines with internet network which enables a whole new level of operating industries in which 4th Industrial Revolution began [4].

According to McGregor, 2017 as cited by David M. and Mary C., after Britain's first industrial revolution, the Fourth Industrial Revolution and Industrial Internet Of Things (IIOT) is the next revolution that involves digital data, connectivity and cyber-system [5]. According to Schlechtendahl, et al. Brettel *et al.*, as cited by Gouveia in Industry 4.0 where organization are connecting individuals and share of information using smart and intelligent products for technologies and in their operational activities [6].

Geissbauer *et al.* cited by Nyberg, Nilsen and Freilich Manufacturing business need fast marketing, more flexibility and be dynamic in terms of innovation which will boost their competence [7]. Industry 4.0 encourage more flexibility, time-efficiency, more customization in smaller quantity, and as well as costs efficiency according to Shafiq *et al.* and Lu. [8]–[10].

B. 4th Industrial Revolution & SME

In recent years, the advent of the Fourth Industrial Revolution has changed the way how industries are more competitive and agile by adopting modern technologies and the internet. According to Andreas, Selim and Wilfried, Industry 4.0 involves advanced technologies integrated with internet network, supports physical objects, human skills, machines and production process in an organization in a smart, connected and efficient manner [11]. Implementing digital technologies for example sensors, Artificial Intelligence (AI) and as well as automation can improve the organization to be more responsive and increase agility to meets customer's demand with the update on technology adoption [12]. They also mention that agility can increase the competitiveness of an organization [5].

According to Within *et al.* [13], the value-chain of an organization needed to be responsive and practical to be competent from the product development stage to the distribution of products. The main characteristic in Industry 4.0 is the smart network for cyber-physical systems [14]. Highly responsive and proactive in all operating activities inside an organization is vital to achieve full optimization and potential in production. According to Arlbjørn and Mikkelsen 2014; Dachs, Kinkel, and J€ager 2019; Di Mauro et al. 2018; Stentoft and Rajkumar 2020; Stentoft *et al.* 2016; Stentoft, Mikkelsen, and Jensen 2016; Tate 2014 as cited by Stentoft *et al.* automation and robotization are the examples of new technologies that helps to relocated manufacturing or moving to manufacture abroad which there is a new revolution called Industry 4.0 that involves computer-generated graphic and physical systems for production [15].

Based on Pachinni's research, there are different maturity models on the adoption of Industry 4.0 technologies from different organizations proposed by different authors. Table II above shows different maturity models from different authors [16]. Leyh *et al.* mention that according to Pöppelbuß and Röglinger that maturity models are for referring to the current level and condition or experience in terms of using technologies and how it helps in developing business organization [17].

TABLE II: DIFFERENT MATURITY MODELS ([16])

Maturity And Readiness Model	Authors
ACATECH Maturity Index	Schuh et al. (2017)
The Singapore Smart Industry Readiness Index	Basil and Doucek (2019)
IMPULS – Industrie 4.0 Readiness	Lichtblau et al. (2015)
DREAMY – Digital Readiness Assessment Maturity Approach	Mittal et al. (2018)
Maturity Approach For Assessing Industry 4.0 Readiness And Maturity Of Manufacturing Enterprises	Schumacher et al. (2016)
SIMMI 4.0 – A Maturity Approach For Classifying The Enterprise-Wide IT And Software Landscape Focusing on Industry 4.0	Leyh et al. (2016)
Industry 4.0: Building The Digital Enterprise	Sarvari et al. (2018)
Concept For An Evolutionary Maturity Based Industrie 4.0 Migration Approach	Stefan et al. (2018)
Three Stage Maturity Model In SME's Towards Industry 4.0	Ganzarain and Errasti (2016)

SMEs need a special maturity model that can be related instead of large enterprises hence organizational dimensions and the maturity levels are needed to be adjusted according to the relevance on SMEs [18]. According to Kohlegger, Maier and Thalmann, as cited by Wagire *et al.*, readiness assessment and maturity evaluation are to lead the whole business on maturing progression and transformation process more effectively and efficiently [19].

Fig. 1 below is the layout of different technologies implemented in the Fourth Industrial Revolution and it also shows the different level of technology adoption where different types of tools fall under it. SMEs are as much important as large enterprises are. Usually larger enterprises are providing a resource to SME and some even took SMEs as their supplier as well which is why SMEs development for Industry 4.0 is crucial and gives an impact on their values [20]. As cited by Olah *et al.*, SMEs need to be more competitive and have a strong performance because these organizations are easily affected comparing to larger and established firms when there is economic turbulence for example in Czech Republic, Hungary, Poland, Slovakia and Serbia as mentioned in their article, SMEs contributed the most in their economic activities [21].

Li *et al.* mentioned, cited by Moeuf *et al.* SMEs are the biggest contributors to industries and countries which they need to have sustainability in their competency to the market [22]. The authors mentioned in the article, to achieve this SME's need to maximise their business processes such as planning, resource allocation, control and production as well as operational performance. Song & Wang mentioned as cited by Ganzarain and Errasti, businesses are having diversification to be more dynamic and strategically planned in doing the new economic activities. To be more competitive and dynamic, the organization must implement Industry 4.0 technologies.

Ganzarain and Errasti argue with Industry 4.0 it will bring changes to the way production, operation and services, design and manufacturing process are carried out. There will be an increase in efficiency and more customization for manufacturing especially with their integration and connectivity of technologies and system resulting in a huge advantage [23]. SMEs need simple machinery and instruments to produce small batches or custom products because they are in a niche market according to Knight as cited by Muller, Buliga and Voigt [20].

Supply chain management in SMEs is one of the important areas that need Industry 4.0 technologies. Radanliev *et al.* agree in their article that small and medium-sized businesses have less knowledge and experiences as well as an option for technologies that are used in large enterprises hence digitalization in the supply chain will precisely affect the small organizations [24]. More research is needed for SMEs to understand and be educated on the implementation of Industry 4.0 and how it benefits the organization. Some SMEs encountered challenges such in terms of cost, time and human skills and knowledge on Industry 4.0.

According to Schmidt *et al.* as cited by Muller, Buliga and Voigt in the article, there is a need to do more research on SMEs because more research was focus on large enterprises emphasized by Arnold *et al.* and Radziwon *et al.* Alexa, Mohammad and Alam also agree in their article that research on Industry 4.0 is only focusing on larger enterprises but less for SMEs [20], [25]. Hence with this research, it is to focus on the current level of adoption of Industry 4.0 technologies on SMEs in two different categories of countries (developing and developed).

III. Categories of Technologies

A. Basic Technologies

Referring to Fig. 1 below in the first category, organizations are implementing very minimal and basic technologies mainly digitalization. Such technologies are Smart Devices (embedded products), the utilization of E-commerce or digitalization i.e. website, social media, messengers, e-mail, online application/software such as Business Management System that is being used for a different department in organizations, for example, finance and accounting system, human resources system, operation and logistic system, marketing, etc.

The characteristics for technologies in this stage are a low-cost investment, easily adaptable which require basic IT skills and high need for the communication processes for reaching out to end-users / customers.

B. Intermediate Technologies

Some micro, small and medium organizations are ready to implement more than basic technologies due to bigger business operation. In the Intermediate Stage, technologies are fairly mid-level in between basic technologies and highly advanced systems. Such technologies in this stage are the use of Big Data Analytics, Cloud systems and Cybersecurity systems. These technologies share the same characteristics i.e. little higher cost for implementation, needs higher skills to handle the system, used for important decision-making for quality products and more efficient communication and operation processes.

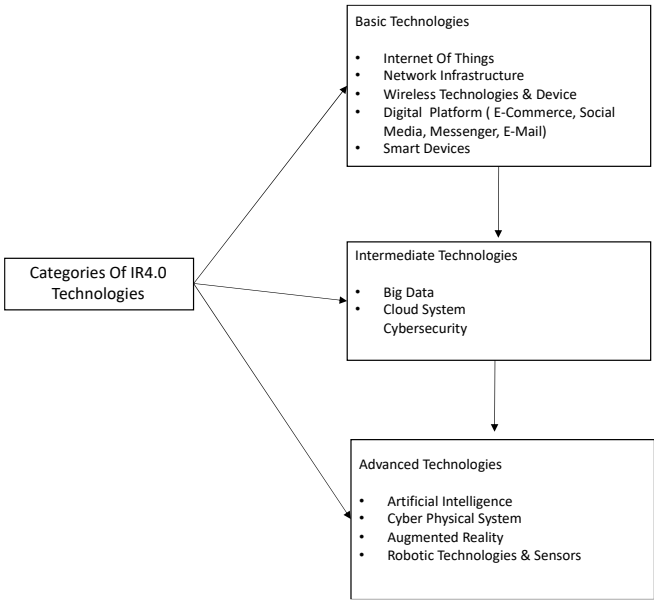

Fig. 1. Different type of technologies.

C. Advanced Technologies

In advanced technologies stage, it involves highly progressive technologies with complex systems. Technologies are Artificial Intelligence, Cyber-physical system, Augmented reality, Robotics and Sensors and advanced machinery and additive manufacturing. The characteristics of these technologies are mainly the high cost of investment, need experts or skilled human resources to handle the system, crucial for decision-making and to boost operation performance, involves in complex algorithmic systems. Organizations in this stage are usually from medium to large-sized and more in the manufacturing or assembly industry.

Due to the page limit, we will not elaborate on the details of the technologies, nevertheless, the categorization has been shown in Table III.

TABLE III: Categorization on Overall Technology Adoption Level

Categories of Overall Technology Adoption Level				
		Level of Technology Adoption		
Overall Categories	Class	Basic Technology	Intermediate Technology	Advanced Technology
Modest	M1.1	Low	Low	Low
	M1.2	Mid	Low	Low
	M1.3	High	Low	Low
Moderate	M2.1	Low	Low	Mid
	M2.2	Low	Mid	Low
	M2.3	Low	Mid	Mid
	M2.4	Low	High	Low
	M2.5	Low	High	Mid
	M2.6	Mid	Low	Mid
	M2.7	Mid	Mid	Low
	M2.8	Mid	Mid	Mid
	M2.9	Mid	High	Low
	M2.10	Mid	High	Mid
	M2.11	High	Low	Mid

	M2.12	High	Mid	Low
	M2.13	High	Mid	Mid
	M2.14	High	High	Low
	M2.15	High	High	Mid
Modernized	M3.1	Low	Low	High
	M3.2	Low	Mid	High
	M3.3	Low	High	High
	M3.4	Mid	Low	High
	M3.5	Mid	Mid	High
	M3.6	Mid	High	High
	M3.7	High	Low	High
	M3.8	High	Mid	High
	M3.9	High	High	High

IV. Overall Categorization of Technology Adoption

In the previous section, we had seen the different levels of technology categorization. However, based on the literature we have observed that the industries are using a various mixture of technologies from different categories. Therefore, to categorize the maturity model of the technology adoption we need to come up with an overall categorization of technology adoption as shown in Table III. This categorization method will determine the current position of a country's level of adoption for IR4.0 technologies as a whole.

Classification of overall categories is by the combination of three levels of adoption which is Low, Mid and High applying permutation. The modest level starts with all three groups of technologies (basic technologies, intermediate technologies, and advanced technologies) implemented at the lowest level. When basic technologies are highly implemented, but the rest of the technologies are low, it automatically falls under the Modest category. In the Moderate category, basic and intermediate technologies are implemented between Low until High, whereas advanced technologies are only implemented between Low and Mid. Hence, the exact classification of classes can be determined by the different combination of technology adoption level as shown in Table III. The moment advanced technologies are Highly implemented, it automatically falls under the Modernized category irrespective of other levels of implementations.

A. Modest

Overall adoption of technologies is modest if:

1. When basic, intermediate, and advanced technologies are lowly implemented.
2. When basic techs are fairly or highly implemented but, advanced and intermediate technologies are low.

B. Moderate

Overall adoption of technologies is moderate if:

1. When basic & intermediate techs are lowly adopted, but advanced technologies are fairly or highly adopted in the organization.
2. When basic and high advanced technologies are low, but intermediate technologies are fairly or highly implemented.
3. When intermediate and advanced technologies are fairly or highly implemented despite low adoption level on basic technologies.
4. When basic, intermediate, and advanced technologies are fairly implemented.
5. When basic and advanced technologies are fairly implemented despite intermediate technology adoption level is low
6. When the intermediate level is high and basic and advanced technologies are fairly implemented.
7. When intermediate is highly adopted and basic techs are fairly implemented despite the low adoption level of advanced technologies.
8. When basic techs are highly adopted, and advanced techs are fairly implemented despite their low adoption level for intermediate technologies.
9. When basic techs are highly adopted, intermediate techs are fairly implemented although advanced technologies are low.
10. When basic techs are highly adopted, intermediate and advances techs are fairly adopted.
11. When basic and intermediate techs are highly adopted, and advanced techs are fairly implemented.

C. Modernized

Overall adoption of technologies is modernized if:

1. When basic, intermediate, and advanced technologies are highly implemented.
2. When advanced techs are high but basic and intermediate techs are lowly implemented.
3. When the adoption level of basic techs is low or fair but intermediate and advanced techs are high.
4. When basic techs are low or fairly adopted but advanced and intermediate techs are high.
5. When basic and advanced techs are high but intermediate techs are fair or lowly implemented.

V. Level of Adoption of Technology in Developed Countries

This research presents four different developed countries and their implementation level for Industry 4.0 technologies by SMEs. After analyzing a few countries from different articles, this finding has shown how SMEs in developed countries is responding to ongoing digitalization. Table IV illustrates the levels of adoption in different developed countries.

TABLE IV: Overall Category on Technology Adoption Level for Germany

Country		Sweden		
No. of Firms		7		
Size		Small	Medium	High
Industry		Heavy Manufacturing		
Type of Tech.	Bas.	Mid	Mid	High
	Int.	Mid	Mid	High
	Adv.	Mid	Low	High
Org. Strategy	Strategy	N/A	N/A	N/A
	Investment	N/A	N/A	N/A
Overall Adoption Level		Moderate	Moderate	Modernized
Reference		Machado *et. al.* 2019		

A. Germany

From the article by Bittighofer *et al.*, a sample of 24 businesses from Germany is focusing on manufacturing,

automation, electronics, engineering and process industries sectors [26]. According to Bittighofer *et al.*, small-sized businesses are fairly implementing basic software and communication tools, moderate level in technologies such as cloud and IT security (Cybersecurity) despite their low adoption on the digital platform. The industries are more focusing on highly advanced technologies which are advanced software, application, moderate level of analytics although low in automation, robotics and sensors.

From this, it shows that even small-sized businesses are using advanced technology more due to their nature of industries in Germany. According to the findings, these industries are keen to strategize for Industry 4.0. Therefore, overall, small-sized businesses in Germany according to their study falls under the category, "Modernized Level" as they are more focused on advanced technologies despite their size.

Medium-sized businesses are implementing more than the reasonable level on basic technologies such as basic software and communication tools. These industries are equipped with moderate employee skills on IT and use modernization of technologies and are implementing mid-level on the advanced software application, automation, robotics, and sensors as well as moderate level on analytics.

According to Bittighofer *et al.* 's findings, these industries are less keen on strategizing for Industry 4.0. Therefore, overall, medium-sized businesses in Germany according to the study falls under the category "Moderate Level" as they are comfortable in their current investment in technologies and sufficient for operating their businesses. Other than that, this research also shows the level of adoption for large-sized businesses in their industries. Mainly they are highly implementing basic technologies both basic software and communication tools. Although these industries are not equipped with moderate employee skills in IT they highly use the digital platform, cloud and cybersecurity in their businesses. The industries are highly adopting analytics, advanced software, application, automation, robotics, and sensors. According to the findings, these industries are less keen on strategizing for Industry 4.0. Therefore, overall, large-sized businesses in Germany according to the study falls under the category "Modernized Level" as they are highly implementing advanced and complex systems in their industries.

B. Sweden

From the article by Machado et al., the study is focusing on manufacturing sectors and gathered a sample of 7 SMEs. According to Machado *et al.*, small-sized businesses are fairly implementing basic software and communication tools, moderate level of technologies such as social media, e-commerce platform for both buyer and supplier, and use digital platform despite their low adoption on cloud and cybersecurity [27].

The industries have a moderate level of adoption on advanced software, application, automation, robotics, and sensors but low on analytics. From this, it shows that even small-sized businesses are using modest to modernized and advanced technologies. There is limited information on strategizing and future investment of Industry 4.0 technologies. Therefore, overall, small-sized businesses in Sweden according to the study falls under the category "Moderate Level" as they are evenly focused on all technologies from basic to advanced. Medium-sized businesses are implementing more than the reasonable level on basic technologies both basic software and communication tools. These industries are not equipped with employee skills on IT, but adopting technologies such as social media, e-commerce platform for both buyer and supplier, and use of digital platform despite their low adoption on cloud and cybersecurity.

TABLE V: OVERALL CATEGORY ON TECHNOLOGY ADOPTION LEVEL FOR SWEDEN

Country		Germany		
No. of Firms		24		
Size		Small	Medium	Large
Industry		Heavy Manufacturing		
Type of Technology	Basic	Mid	Mid	High
	Int.	Mid	Mid	High
	Adv.	High	Mid	High
Org. Strategy	Strategy	High	Low	Low
	Investment	N/A	N/A	N/A
Overall Adoption Level		Modernized	Moderate	Modernized
Reference		Bittighoffer *et al.* 2018		

The level of implementation for advanced software, application, autonomation, robotics, and sensors are low. There is limited information on interest in strategizing and future investment of Industry 4.0 technologies. Therefore, overall, medium-sized businesses in Sweden according to the study falls under the category "Moderate Level" as they are evenly focused on all technologies from basic to intermediate despite the low adoption of modernized technologies. Other than that, this research also shows the level of adoption for large-sized businesses in their industries. Mainly they are highly implementing basic technologies, both basic software and communication tools.

These industries are adequately equipped with employee skills in IT and highly using the digital platform, cloud and cybersecurity, social media, and e-commerce platform for both buyer and supplier in their business. The industries are highly adopting advanced software, application, automation, robotics, and sensors, but low on analytics. There is limited information on interest for strategizing and future investment of Industry 4.0 technologies. Therefore, overall, large-sized businesses in Sweden according to the study falls under the category "Modernized Level" as they are highly adopting advanced technologies as well as basic and intermediate

technologies.

C. South Korea

According to Sheen, a sample of 110 SMEs in South Korea is implementing moderate level for basic, intermediate and advanced technologies. The industries focused on this article are only in the manufacturing industry [28]. Based on the findings, South Korea's manufacturing industry is highly adopting basic technologies for communication and ICT software. There is limited information on the rate of implementing other intermediate technologies, but these industries are having moderate IT skills for human resource. South Korea also having a moderate level of advanced technologies such as automation system, robots and sensors and advanced software. The study referred above also show that the industries have an interest in strategizing for Industry 4.0 technologies. Therefore, overall small and medium manufacturing industries according to the study falls under the category "Moderate Level" as they are implementing all technologies from basic to advanced.

TABLE VI: OVERALL CATEGORY ON TECHNOLOGY ADOPTION LEVEL FOR SOUTH KOREA AND NEW ZEALAND'S

Country		South Korea			New Zealand
No. Of Firms			110		43
Size		SME	Medium	High	SME
Ind.				Manufacturing	
Type of Tech	Bas.	Mid	Mid	Mid	Mid
	Int.	Mid	Mid	Mid	Low
	Adv.	Mid	Mid	Mid	High
Org. Strategy	Strategy	Mid	Mid	Mid	Mid
	Investment	N/A	N/A	N/A	Positive
Overall Adoption Level		Moderate	Moderate	Modernized	Modernized
Reference			Sheen 2019		Hamzeh, Zhong, and Xu 2018

TABLE VII: OVERALL CATEGORY ON TECHNOLOGY ADOPTION LEVEL FOR BRAZIL, MALAYSIA & INDONESIA

Country		Brazil	Malaysia	Indonesia
No. of Businesses		92	250	280
Size		SME	SME	SME
Industry		Manufacturing	Various Industry	Various Industry
Type of Tech.	Bas.	Mid	Mid	High
	Int.	Mid	High	High
	Adv.	Mid	High	N/A
Organization & Strategy	Strategy	N/A	Low	N/A
	Investment	N/A	Positive	N/A
Overall Adoption Level		Moderate	Modernized	Moderate
Reference		Frank, Dalenogare, and Ayala 2019	Hamidi *et al.* 2018	Rahayu and Day 2015

A. New Zealand

From the article Hamzeh, Zhong and Xu this study focus on 43 manufacturing business industries in New Zealand [29]. Referring to the Table VI above, he level of basic technologies adoption is high although real-time communication tools are lowly adopted. This is a problem for the industries especially for delivering customer service. There is limited information on other intermediate technologies, but these industries are encountering low-level of skilled IT employees. Manufacturing sectors in New Zealand are highly focusing on manufacturing technologies which are advanced software application such as ERP, accounting systems, CRM, automation but low on robotics and sensors. These industries are keen to strategize and have the potential to invest in Industry 4.0 technologies for the future. Overall, New Zealand's manufacturing industry is in the "Modernized Level" because of highly implementing software and autonomous technology for improving their production.

VI. LEVEL OF ADOPTION OF TECHNOLOGY IN DEVELOPING COUNTRIES

A. Brazil

As illustrated in Table VII above, the study of Brazil shows they are focusing on 92 SMEs in the manufacturing industries. The industries are adopting fairly moderate IoT, basic software and communication tools [28]. They have a low implementation on e-commerce platforms, but however moderate level on social media, e-payment, digital platform and the cloud. In terms of modernized technologies, there is a low adoption level for the use of the application, analytics, automation, and robotics but fairly moderate on advanced software. There is limited information on interest to strategize or invest in Industry 4.0 technologies. Overall, Brazil's small and medium manufacturing industry falls under the category "Moderate Level" because of the existence of basic to advanced technologies.

B. Malaysia

The study from Hamidi *et al.* focuses on various industries

across 250 SMEs in Malaysia [30]. The industries in Malaysia are adopting fairly moderate IoT, basic software and communication tools. They have low IT skill availability but high implementation on cloud and cybersecurity. There is limited information found concerning the implementation of e-commerce platforms, social media, e-payment, and digital platform. In terms of modernized technologies, there is a low adoption level for the use of the application, analytics, automation and robotics but fairly moderate on advanced software. There is low interest for the SME to strategize but there is some positive reaction to invest in Industry 4.0 technologies. Overall, Malaysia SME's industries fall under the category "Modernized Level" because of implementing moderate basic technologies, equipped with IT skills even if it is low and there are adequate adoption of advanced software technologies.

C. Indonesia

According to the study from Rahayu focus on various industries across 280 SMEs in Indonesia [31]. The industries in Indonesia are highly adopting basic software and communication tools. They have moderate skill in IT for human resource and highly implementing digital platform and e-commerce platform. The industries are also adopting e-payment technologies well although there is limited information on cloud and cybersecurity. This paper only focuses on the adoption of IoT technologies in Indonesia, therefore there is limited information on advanced technologies. Overall, Indonesia's small and medium industries fall under the category "Moderate Level" because of the great adoption of IoT technologies.

TABLE VIII: OVERALL CATEGORY TECHNOLOGY ADOPTION LEVEL FOR TAIWAN

Country		Taiwan					
No. of Firm		80					
Size		Large & SME	SME, EMS	EMS	SME,	EMS	
Industry		ITC Man.	Traditional Industries	ICT & Man.	ICT Peripherals	Components	Software Firm
Type of Tech.	Bas.	High	Mid	High		Low	
	Int.	High	Mid	High		Low	
	Adv.	High	Mid	High		Low	
Organization & Strategy	Strategy	N/A	N/A	N/A		N/A	
	Investment	N/A	N/A	N/A		N/A	
Overall Adoption Level		Modernized	Moderate	Modernized		Modest	
Reference		Lin, Wang, and Sheng 2020					

D. Taiwan

Referring to the Table VIII above, research from Lin, Wang and Sheng, 80 of Taiwan's industries are divided into several large categories such as SMEs in the ICT industry, SMEs in the traditional industry, Environmental Management System (EMS) for ICT manufacturing and EMS for ICT peripherals components and software firms [32]. The study found large businesses, SMEs and EMS industries are adopting a high level of basic software and communication tools. These industries are also highly adopting intermediate technologies which are e-commerce, e-payment, digital platform, cloud and cybersecurity. They also have a high level of skilled people for Industry 4.0 technologies. Other than that, these industries are optimizing their level of adoption on advanced technologies from software, application, analytics, automation, robotics and sensors.

Overall, these SMEs fall under the category "Modernized Level" because the nature of the industries is involving the production of ICT products and software which require a high level of Industry 4.0 technologies. The traditional industries for SMEs and EMS, are adopting moderate basic technology and communication tools. These industries are also adopting adequate intermediate technologies which are e-commerce, e-payment, digital platform, cloud, and cybersecurity. They also have a moderate level of skilled people for Industry 4.0 technologies. These industries have mid-level adoption of advanced technologies from software, application, analytics, automation, robotics and sensors. Overall, these SMEs fall under the category "Moderate Level" because the nature of the industries is involving system design, mechanical and tooling process.

VII. COMPARISON OF ADOPTING IR4.0 BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

In this paper, we have identified different patterns in the adoption of Industry 4.0 technologies from different categories of countries. Our results show that level of adoption in developed countries is only slightly advanced in comparison to developing countries. Developed countries have a higher level of adoption for basic, intermediate, and advanced technologies in comparison to developing countries. Most of these SMEs in developed countries have moderate employee skills in handling technologies, this could be the reason why they are at a higher level. According to Jackson, Chuang, Harden and Jiang as cited by Buchan, Zeifang and Leu, the transfer and share of knowledge of information are vital for employees and the whole group for effective innovation [33]. In some countries, lacking knowledge and exposure can be a barrier in implementing technologies moreover if there are limited relevant resources for the business. According to Chonsawat and Sopadang, the reason why there is low adoption of technologies are because there is insufficient knowledge in terms of development and improvising technologies in business and SMEs are lacking information on where to get the needed technologies [34].

The study also shows SMEs in developed countries are keen to strategize for Industry 4.0 to gain a competitive advantage for their businesses. According to Dassisti, M., et al. and Schmeisser, Dopfer cited by Voell, Chatterjee and Rauch adopting strategies to Industry 4.0 will be a challenge to SMEs, moreover, large companies are predicting the potential

and risk of digitization and started innovation when SMEs are facing issues on implementing Industry 4.0 [35]. But in this research, there are few businesses in some countries that are positive in initiating to strategize for Industry 4.0 for a better future.

According to Qomariyah and Priandoyo, adopting Industry 4.0 technologies in the organization will be complicated hence the company must be ready to strategize. Slow adoption can be resulted from a lack of motivation to change the business strategy, operation of the plan and lack of business strategy alignment [36]. Unlike developed countries, there are more support and help from the government and other bodies that encourage more revolutionized technologies and there are strong push factors in gaining more competitive advantage. The level of advanced technology adoption in developing countries are lower compare to developed countries. The reason behind the low implementation of technologies could be because of lacking resources, different level of industry field, insufficient support and awareness on Industry 4.0 and cultural factors.

According to Sari and Santoso, local government should help to educate micro and small businesses based on what their business needs to have an impact. Methods of educating can be by having micro-business groups focusing on managerial factors and second, helping small and medium scale business with human resource training and explore the potential benefit of technologies in businesses [37]. With such aids, this can introduce potential Industry 4.0 technologies in businesses. According to Romer, Mattson and Fast-Berglund, SMEs are often encountering challenges in terms of safety and data protection, loss of authority for their data, expensive implementation, high effort to implement which requires more time that affects the existing processes [38]. Takakuwa, Veza and Celar mentioned in their article, there are few initiatives in different developed countries for Industry 4.0 strategy which are Made In China by China, Productivity 4.0 by Taiwan, Manufacturing Innovation 3.0 Initiative and I-Korea 4.0 by South Korea and Society 5.0 by Japan [39]. These countries have initiated implementing advanced technologies and now benefitting from the revolution.

VIII. Conclusion and Future of Research

SMEs in developed countries are implementing slightly higher technologies. They have employees with skills and knowledge, strategizing for competitive advantage, gained more support from the government and other bodies. Whereas for developing countries, there are lacking support and awareness in understanding digitalization. Not only that, lack of resources and cybersecurity concern are few other challenges that hinder implementing technologies.

Different countries have different levels of utilizing technologies according to the type of industries, it is suggested to do more industry-specific study to gain more in-depth understanding. The future direction for the research will be to identify the level of adoption of Industry 4.0 in the perspective of Brunei Darussalam and as well as to investigate different drivers and barriers in implementing Industry 4.0 technologies by SMEs and MSMEs.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors contributed equally and approved the final version.

Acknowledgement

We thank University Technology Brunei and Brunei Government Scholarship Scheme for support and funding in carrying out this research.

References

[1] History.com Editors. (Sep. 09, 2019). Industrial revolution: Definitions, causes & inventions – History. *A&E Television Networks*. [Online]. Available: https://www.history.com/topics/industrial-revolution/industrial-revolution

[2] M. Xu, J. M. David, and S. H. Kim, "The fourth industrial revolution: Opportunities and challenges," *Int. J. Financ. Res.*, vol. 9, no. 2, pp. 90–95, 2018, doi: 10.5430/ijfr.v9n2p90.

[3] W. S. Alaloul, M. S. Liew, N. A. W. A. Zawawi, and I. B. Kennedy, "Industrial revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders," *Ain Shams Eng. J.*, vol. 11, no. 1, pp. 225–230, 2020, doi: 10.1016/j.asej.2019.08.010.

[4] L. Agostini and A. Nosella, "The adoption of Industry 4.0 technologies in SMEs: Results of an international study," *Manag. Decis.*, vol. 58, no. 4, pp. 625–643, 2019, doi: 10.1108/MD-09-2018-0973.

[5] G. M. David and H. C. Mary, "Understanding the role of logistics capabilities in achieving supply chain agility: A systematic literature review David," 2011.

[6] H. Gouveia, "Assessing industry 4 . 0 readiness," *Progress in Digital and Physical Manufacturing*, vol. 1, no. May 2020, pp. 57–64, 2020, doi: 10.1007/978-3-030-29041-2.

[7] E. Nyberg, S. Nilsen, and J. Freilich, "The adoption of Industry 4.0 technologies in manufacturing – A multiple case study," *KTH Ind. Eng. Manag.*, p. 79, 2016, doi: 10.1007/s00464-002-8769-y.

[8] S. I. Shafiq, C. Sanin, E. Szczerbicki, and C. Toro, "Virtual engineering factory: Creating experience base for industry 4.0," *Cybern. Syst.*, vol. 47, no. 1-2, pp. 32–47, 2016, doi: 10.1080/01969722.2016.1128762.

[9] S. I. Shafiq, C. Sanin, C. Toro, and E. Szczerbicki, "Virtual engineering object (VEO): Toward experience-based design and manufacturing for industry 4.0," *Cybern. Syst.*, vol. 46, pp. 35–50, 2015, doi: 10.1080/01969722.2015.1007734.

[10] Y. Lu, "Industry 4.0: A survey on technologies, applications and open research issues," *J. Ind. Inf. Integr.*, vol. 6, pp. 1–10, 2017, doi: 10.1016/j.jii.2017.04.005.

[11] S. Andreas, E. Selim, and S. Wilfried, "A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises," in *Proc. the International Conference on Industrial Engineering and Operations Management*, 2016, doi: 10.1016/j.procir.2016.07.040.

[12] C. Jones and P. Pimdee, "Innovative ideas: Thailand 4.0 and the fourth industrial revolution," *Asian Int. J. Soc. Sci.*, vol. 17, no. 1, pp. 4–35, 2017, doi: 10.29139/aijss.20170101.

[13] P. Within *et al.*, *Impacts of Swedish Manufacturing SMEs Context*, no. May, 2019.

[14] L. Barreto, A. Amaral, and T. Pereira, "Industry 4.0 implications in logistics: An overview," *Procedia Manuf.*, vol. 13, no. December, pp. 1245–1252, 2017, doi: 10.1016/j.promfg.2017.09.045.

[15] J. Stentoft, K. Adsbøll Wickstrøm, K. Philipsen, and A. Haug, "Drivers and barriers for industry 4.0 readiness and practice: Empirical evidence from small and medium-sized manufacturers," *Prod. Plan. Control*, pp. 1–18, 2020, doi: 10.1080/09537287.2020.1768318.

[16] A. P. T. Pacchini, W. C. Lucato, F. Facchini, and G. Mummolo, "The degree of readiness for the implementation of Industry 4.0," *Comput. Ind.*, vol. 113, p. 103125, 2019, doi: 10.1016/j.compind.2019.103125.

[17] C. Leyh, T. Schäffer, K. Bley, and L. Bay. (August, 2017). The application of the maturity model SIMMI 4 . 0 in selected enterprises full paper chair of information systems chair of information systems. *Twenty-Third Am. Conf. Inf. Syst.*, [Online]. pp. 1–10, 2017. Available: https://pdfs.semanticscholar.org/ce1e/e1bf3faf17b67d3ff835bdd21d610c29fb58.pdf

[18] S. Mittal, D. Romero, and T. Wuest, "Towards a smart manufacturing toolkit for SMEs," *IFIP Adv. Inf. Commun. Technol.*, vol. 540, no. August, pp. 476–487, 2018, doi: 10.1007/978-3-030-01614-2_44.

[19] A. A. Wagire, R. Joshi, A. P. S. Rathore, and R. Jain, "Development of maturity model for assessing the implementation of Industry 4.0: learning from theory and practice," *Prod. Plan. Control*, pp. 1–20, 2020, doi: 10.1080/09537287.2020.1744763.

[20] J. M. Müller, O. Buliga, and K. I. Voigt, "Fortune favors the prepared: How SMEs approach business model innovations in industry 4.0," *Technol. Forecast. Soc. Change*, vol. 132, no. September, pp. 2–17, 2018, doi: 10.1016/j.techfore.2017.12.019.
[21] J. Oláh, S. Kovács, Z. Virglerova, Z. Lakner, M. Kovacova, and J. Popp, "Analysis and comparison of economic and financial risk sources in SMEs of the Visegrad Group and Serbia," *Sustain.*, vol. 11, no. 7, pp. 1–19, 2019, doi: 10.3390/su11071853.
[22] A. Moeuf, R. Pellerin, S. Lamouri, S. Tamayo-Giraldo, and R. Barbaray, "The industrial management of SMEs in the era of Industry 4.0," *Int. J. Prod. Res.*, vol. 56, no. 3, pp. 1118–1136, 2018, doi: 10.1080/00207543.2017.1372647.
[23] J. Ganzarain and N. Errasti, "Three stage maturity model in SME's towards industry 4.0," *J. Ind. Eng. Manag.*, vol. 9, no. 5, pp. 1119–1128, 2016, doi: 10.3926/jiem.2073.
[24] P. Radanliev, D. C. De Roure, J. Nurse, R. M. Montalvo, and P. Burnap, "Supply chain design for the industrial internet of things and the industry 4.0," *SSRN Electron. J.*, vol. 0, pp. 1–10, 2019, doi: 10.2139/ssrn.3346528.
[25] L. Alexa, M. Mohammad, and D. Alam, *Industry 4.0 Adoption. An Overview of European Union Enterprises*, no. January, 2020.
[26] D. Bittighofer, M. Dust, A. Irslinger, M. Liebich, and L. Martin, "State of industry 4.0 across German companies," in *Proc. 2018 IEEE Int. Conf. Eng. Technol. Innov. ICE/ITMC 2018*, pp. 1–8, 2018, doi: 10.1109/ICE.2018.8436246.
[27] C. G. Machado, M. Winroth, D. Carlsson, P. Almström, V. Centerholt, and M. Hallin, "Industry 4.0 readiness in manufacturing companies: Challenges and enablers towards increased digitalization," *Procedia CIRP*, vol. 81, pp. 1113–1118, 2019, doi: 10.1016/j.procir.2019.03.262.
[28] D. Sheen, "2019 IEEE Technology and Engineering Management Conference, TEMSCON 2019," *2019 IEEE Technol. Eng. Manag. Conf. TEMSCON 2019*, 2019.
[29] R. Hamzeh, R. Zhong, and X. W. Xu, "A survey study on industry 4.0 for New Zealand manufacturing," *Procedia Manuf.*, vol. 26, pp. 49–57, 2018, doi: 10.1016/j.promfg.2018.07.007.
[30] S. R. Hamidi, A. A. Aziz, S. M. Shuhidan, A. A. Aziz, and M. Mokhsin, "SMEs maturity model assessment of IR4.0 digital transformation," *Adv. Intell. Syst. Comput.*, vol. 739, pp. 721–732, 2018, doi: 10.1007/978-981-10-8612-0_75.
[31] R. Rahayu, "E-commerce adoption by small and medium sized enterprises in Indonesia: An empirical study of influencing factors and the impact of e- commerce adoption on SME performance," Dr. Philos. thesis, 2015.
[32] T. C. Lin, K. J. Wang, and M. L. Sheng, "To assess smart manufacturing readiness by maturity model: A case study on Taiwan enterprises," *Int. J. Comput. Integr. Manuf.*, vol. 33, no. 1, pp. 102–115, 2020, doi: 10.1080/0951192X.2019.1699255.
[33] J. Puchan, A. Zeifang, and J. Leu, "Industry 4 . 0 in practice – identification of industry 4 . 0 success patterns," pp. 1091–1095, 2018.
[34] N. Chonsawat and A. Sopadang, "The development of the maturity model to evaluate the smart SMEs 4.0 readiness," in *Proc. Int. Conf. Ind. Eng. Oper. Manag.*, vol. 2019, no. Mar., pp. 354–363, 2019.
[35] C. Voell, P. Chatterjee, and A. Rauch, *Closing the Lifecycle Loop with Installed Base Products*, vol. 540, no. July, 2018, Springer International Publishing.
[36] R. Maskuriy, A. Selamat, K. N. Ali, P. Maresova, and O. Krejcar, "Industry 4.0 for the construction industry—How ready is the industry?" *Appl. Sci.*, vol. 9, no. 14, p. 2819, 2019, doi: 10.3390/app9142819.
[37] R. P. Sari and D. T. Santoso, "Readiness factor identification on Kabupaten Karawang SMEs towards industry 4.0 Era," *J. Tek. Ind.*, vol. 22, no. 1, pp. 65–74, 2020, doi: 10.9744/jti.22.1.65-74.
[38] D. Romero, S. Mattsson, and Å. Fast-berglund, *Advances in Production Management Systems. Smart Manufacturing for Industry 4.0*, vol. 536, no. June 2019, Springer International Publishing, 2018.
[39] S. Takakuwa, I. Veza, and S. Celar, "'Industry 4.0' in Europe and east Asia," in *Proc. Int. DAAAM Symp.*, vol. 29, no. 1, pp. 61-69, 2018, doi: 10.2507/29th.daaam.proceedings.009.

Nurul Izzati Naqibah is a PhD scholar in management, UTB School of Business at University Technology Brunei. Her current research interest includes small & medium entrepreneurship, technology adoption and Industry 4.0.

Mohamed Saleem Nazmudeen is a senior assistant professor at UTB School of Business, Brunei Darussalam. He received his PhD from University Technology Petronas, Malaysia. His research interests include (but not limited to) MIS, business intelligence, operations and social media analytics.

Fadzliwati Mohiddin is a principal lecturer at UTB School of Business, Brunei Darussalam. She received her MBA from Lancaster University, UK and PhD in information systems from Curtin University of Technology, Australia. Her current research interest includes information systems' success, knowledge management and e-government.