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A NOVEL FRAMEWORK AND STRATEGIES SUPPORTING IR 4.0 RELATION TO MANUFACTURING PROCESS

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THANK YOU

A NOVEL FRAMEWORK AND STRATEGIES SUPPORTING IR 4.0 RELATION TO MANUFACTURING PROCESS

Prof. Dr Yusri Bin Hj Yusof

Abstract

Transforming manufacturing industry from conventional based to digital based is not a short-term process, with many industries having experienced significant challenges for decades to be more flexible, interoperable, adoptable, open and intelligent. Industry 4.0 is vision for the future, because it includes several features and appearances many types of complexities and challenges, including scientific challenges, technological difficulties, economic challenges, human problems, and political issues. This publication generally highlights the framework and strategies advancement of IR 4.0 and its effect on CNC's world. Generally, the developments of these kinds of systems are high in cost. The commercial CNC systems, based on IR 4.0 using personal computers as it platform, provides wide options for the use of third party hardware and software. Overall, the combination of virtual component technology from both software and hardware with STEP has highlighted numerous field of research which led to the opening new doors for further improvement and contributions for preparing Malaysia towards IR 4.0.

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CHAPTER 1

INTRODUCTION

1.1 Preamble

Over the past more than 200 years, technologies have been playing a dominant role in increasing industrial productivity, which was demonstrated by the previous three industrial revolutions, i.e., mechanization (powered by steam engines in the 1800s), mass production (powered by electricity and the assembly line in the early 1900s), and automation (powered by computers in the late 1900s.

Nowadays, information and communication technology in particular, the Internet and embedded systems technologies is undergoing rapid development, which has given rise to a number of novel technologies, such as cyber-physical systems (CPS), the Internet of things (IoT), cloud computing, and big data analytics. The advent of these new technologies enables the creation of a smart, networked world, in which "things" are endowed with a certain degree of intelligence, and moreover, being increasingly connected to each other. In the manufacturing field, the widespread deployment of sensors and the extensive application of software in industrial production bring together the physical and virtual worlds, giving rise to CPS. Moreover, with the help of the internet, a great variety of manufacturing things and "services" can be connected to create the things and services.

Internet, i.e., IoT and Internet of services (IoS). All these transformations mark the transition of current industrial production to the fourth stage Industry 4.0, which is characterized by smartness and networking. Industry 4.0, referred to as the "Fourth Industrial Revolution", also known as "smart manufacturing", "industrial internet" or "integrated industry", is currently a much-considered issue that supposedly has the possible to affect entire industries by changing the way goods are designed, manufactured, distributed and paid.

Industry 4.0 will be a modern the industrial revolution, which will have a big influence on global manufacturing. This can proved by the number of article related to industry 4.0 grows every year as shown in Figure 1.1. Since China's manufacturing is currently in a phase of industrial change and upgrading, Industry 4.0 provides China with further and challenges that we should be focussing on. Germany is one of the common ambitious global manufacturing industries, and is a machine manufacturing industry's global leader in several fields, including BMW, Porsche and Volkswagen in the automotive industry, the sports brand Adidas, the electrical and electronics company Siemens.

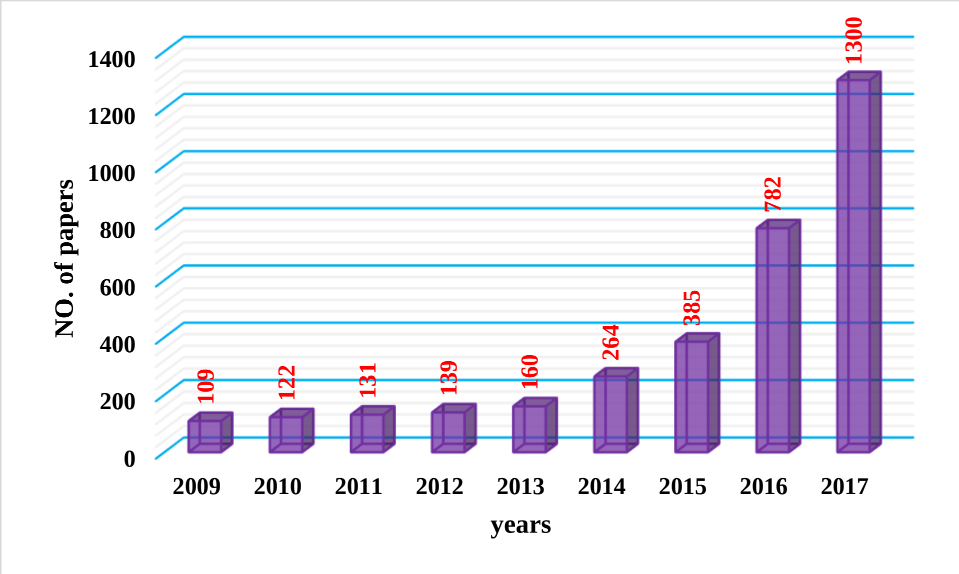

Figure 1.1 The number of industry 4.0 articles by year

In response to the European debt crisis, the German Government presented a plan for Industry 4.0, in order to further, incorporate and advance global German manufacturing clout. Industry 4.0 is an important enterprise of the German government that was adopted as part of the "High-Tech Strategy 2020 Action Plan" in 2011 (Kagermann, Wahlster, Helbig, 2013). In Germany, a significant discussion on Industry 4.0 has begun, which in the meanwhile has developed also to other countries, like the US or Korea or China. The concept is that the first three industrial revolutions occurred about as a result of industrialization, electricity and IT. Now, the introduction of the IoT and CPS into the manufacturing environment is leading to a 4th Industrial Revolution [1].

The goal of the 4.0 industry is to develop the product model is greatly flexible of and digital Products and services, with real-time communications between People, products, and devices during the production process. For example, a company that accepts customer orders and immediately provided the required product ships will distribute of separate selling and exchanging ways, which will have A big influence on the traditional e-commerce sales model. Industry 4.0 will affect not only the German industry, or even International industrial development but will become leadership Government which will change the conventional industrial techniques Generation, and future manufacturing introduction [2].

1.2 Challenges for Industry 4.0

It is not an easy matter to realize Industry 4.0, and it is likely to take ten or more years to achieve. Currently, Industry 4.0 is vision for the future, because it includes several features and appearances many types of complexities and challenges, including scientific challenges, technological difficulties, economic challenges, human problems, and political issues as shown in Figure 1.2.

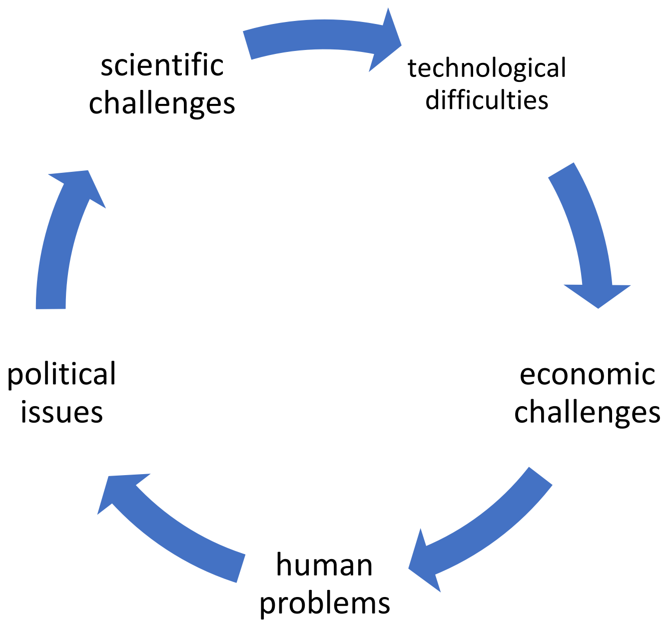

Figure 1.2 Different challenges of Industry 4.0

1.3 The Internet of Things (IoT)

The Internet of Things (IoT), also called the Internet of Everything or the Industrial Internet, is a modern technology model envisioned as a global network of machines and devices intelligent of combining with each other. The IoT is identified as one of the most significant fields of future technology and is getting large application from a wide range of enterprises. The true value of the IoT for enterprises can be fully realized when connected devices are able to communicate with each other and integrate with vendor-directed inventor systems, consumer support systems, enterprise intelligence applications, and business analytics.[3] Predictions that the IoT will reach 26 billion units by 2020, up from 0.9 billion in 2009, and will improve the information available to provide chain partners and how the supply chain works. From product line and warehousing to retail distribution and stocks shelving, the IoT is transforming business processes by providing more accurate and real-time visibility into the flow of materials and products. Firms will invest in the IoT to redesign factory workflows, develop tracking of materials, and optimize distribution costs. According to a study by American Society for Quality (ASQ) in 2014, 82 percent of companies that claim to have achieved smart manufacturing say that they have experience increased performance. However, 49 percent encountered some product defects and 45 percent experienced increased customer delight"[4]. Also, the Economist Intelligence Unit estimated the current and future use of the IoT through running a survey in June, 2013 on the global business community: according to their results, 38 percent of respondents consider that the IoT will have a major influence on most businesses and industries. Three years from survey time, 96 percent of the respondents expect their business to be using the IoT in some respect, 63 percent believe that "companies slow to integrate the IoT will fall behind the competition" and 45 percent believe "adopting the IoT will make the company more environmentally friendly.

The connection between smart factories and customers in industry 4.0 that is approved by IoT technology. The smart organizations give the consumers with smart commodities and services which will be attached to the internet. Then, the smart organizations will collect and analyse data coming from the smart products and related smart applications. This analysis allows the organizations to better define customers' reactions and needs and to give them with new and more sustainable products and services. In addition to that, IoT technology allows the customers to be included in product design process.

1.4 Cloud Manufacturing

The introduction strength of globalization helped to immediately combine characters from all over the globe, making with it game-changing possibilities to give acquaintance and expertise to profit in a corporate manner. [5] describes that the modern globalization form, which he coins Globalization 3.0, started around the year 2000 and was facilitated by the extension of the internet on a global basis during the dot-com boom. Remaining in an expanding globalization, today's manufacturing organizations are concentrating on selecting more cost-effective manufacturing systems to survive competitively. The success of much global manufacturing companies relies on the incorporation of their manufacturing capabilities across the globe. With a comprehensive integration of their designated product improvement methods and manufacturing processes, they are realizing and getting the benefit of the many advantages of resource coordination and distribution [6].

Current manufacturing has become from increasing product scale in the 1960s, reducing product cost in the 1970s, raising product quality in 1980s, responding to exchange in 1990s, to emphasizing knowledge and services in the today's [7]. A difference of advanced manufacturing systems (AMS) and forms have been introduced. The standard ones are Computer Integrated Manufacturing (CIM) [8]–[10] Computer-integrated manufacturing (CIM) is the use of computer techniques to integrate manufacturing activities. These activities encompass all functions necessary to translate customer needs into a final product, flexible manufacturing (FM) [11], concurrent engineering [12], green manufacturing [13], sustainable manufacturing and global manufacturing [14]. Thus the number of cloud manufacturing articles has grown over the years as shown in Figure 1.3.

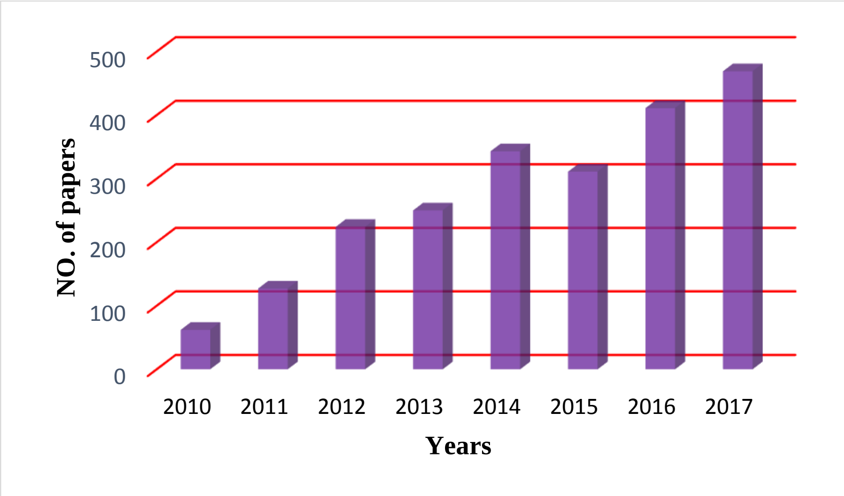

Figure 1.3 The number of cloud manufacturing articles by year

After more of development, these AMSs become playing a significant performance in the development of advanced manufacturing and industry. and AMSs conform to the aims and requirements of informatization, globalization, and more technologies have been proposed, including manufacturing source and service modelling and encapsulation [15] [16], resource and service optimal allocation and scheduling [17]–[21], service workflow administration [22] [23], and supply series administration[24]. Now, information and advice technology in special, the Internet and implanted systems technologies is knowing agile improvement, which has given growth to a number of new technologies, such as cyber-physical systems (CPS), the Internet of thing (IoT).

Table 1.1 Comparison of Description

Reference	Description of cloud manufacturing
(Bohu et al., 2010) [25]	Cloud manufacturing is a service-oriented, technologic-founded Intelligent production system with large capacity and reducing power utilizing
(Fei Tao, 2011)[26]	Cloud manufacturing is a modern service-oriented manufacturing design and it combines various technologies to promote cooperation, distribution and administration of manufacturing sources such as cloud computing, virtualization and service-oriented technologies
(Mezgár, 2011)[27]	Cloud manufacturing produces collaborative production conditions for manufacturing industries are a combined promoting environment for the distribution of sources in an Enterprise. It gives implicit manufacturing resource supplies,
(Tai & Xu, 2012)[28]	Cloud manufacturing is a latest service-oriented, effective and energy-profit, knowledge-based, networked smart manufacturing design. Different manufacturing sources can be used in the cloud service program, and they are distributed by several compound cooperation manufacturing needs. The co-operation is used to support for all steps in the full world of manufacturing, including product design, simulation, investigation,
(Kłosowski, 2012)[29]	Cloud manufacturing is a representation for allowing universal, accessible, on-demand network path to an accorded supply of configurable manufacturing sources (e.g. manufacturing software instruments, manufacturing tools, and manufacturing abilities) which can be published with minimal control effort or co-operation provider interaction
(D. Wu, 2013)[30]	Cloud manufacturing is client-based production Design that uses on-demand input for a specific set of diverse and dispersed manufacturing sources to create temporary, modular production lines that improve performance, overcome product lifecycle costs and support for optimal Resource minimal management effort or service provider interaction
(Adamson, 2017)[31]	Cloud Manufacturing is a current manufacturing model created on resource distribution, making this change. It is envisioned that corporations in all areas of manufacturing will be ready to package their resources and know-how in the Cloud,
(Liu & Xu, 2017)[32]	Cloud manufacturing is a modern service-oriented enterprise model based on the cloud concept and method.
(Yao,2015)[33]	Cloud manufacturing is an intelligently networked manufacturing paradigm as well as a combined technology that empowers service-oriented personalized manufacturing

Cloud computing, and big data analytics enables the making of an intelligent, networked world. Cloud Computing is a modern term for a long-held vision of computing as a service [34] which has lately appeared as an economic certainty. Cloud computing has evolved the industry paradigm and the modus-operandi of many areas of the business enterprise. There are various comparison of description for cloud manufacturing as shown in Table 1.1. One of the areas affected by the advances in information technology and cloud computing is the manufacturing area where the cloud manufacturing paradigm is emerging.

Cloud manufacturing is the latest manufacturing criterion. Remains one of the innovative approach core empowerment technologies for a smart manufacturing enterprise and its growing application in manufacturing research. [26], [35]–[37]. Several authors have proposed definitions of CM .In 2010 define cloud manufacturing to be ‘a service-oriented, knowledge-founded intelligent manufacturing system with the large ability and low power expenditure [37]. [26] define cloud manufacturing to be a current service-oriented manufacturing paradigm, which combines various technologies so as networked manufacturing, cloud computing, Internet of Things (IoT), and service-oriented technologies to encourage collaboration, distribution and administration of manufacturing sources. the Many hundreds of articles have been published which started suddenly growing, the authors conveyed an extended literature review by reviewing relevant features from major academic databases (IEEE Xplore, Web of Knowledge Science Direct) to help involved researchers understand the modern situation and future research possibilities of cloud manufacturing Table 1 defines the concept of cloud manufacturing done by various researchers.

1.5 An overview of cloud manufacturing

The consumers’ satisfaction is embedding from the quality of the product, produced by a manufacturing company [38]. The feature, despite, heavily depends on the status of the devices. Thus, their maintenance is a thing of big attention to maintaining their production as close to the new as likely as probable [39]. Advanced technology support maintenance techniques that enhance the sustainability of production systems. Cloud manufacturing needs collaboration between different technologies in order to improve its abilities to accomplish complex, large-scale manufacturing services and responsibilities [40] the state of the art means that modular systems and multi-layer structures are the most popular plan to build the cloud manufacturing platform or system framework. The control of services within cloud manufacturing is deemed to be a significant matter, as it needs efficient managing and adjusting to the resources and abilities manufacturing accomplish on-demand services through the cloud [41], integration of resources and abilities can happen between various clouds, as Zhang et al [35] identify, there may be two types of clouds (general clouds and Private clouds) and therefore resources interact depending on the industry requirements.

Comrade networks and large exploitation usually impede their capacity to develop and to successfully manage critical manufacturing businesses, e.g. increasingly complicated product designs, matching manufacturing companies with resource ability and capacity, loss of a resource and capacity high costs, and expensive and complicated IT systems [42] CIM is the combination of the complete manufacturing industry through the performance of integrated systems and data connections coupled with the new managerial knowledge that improves organizational and personal productivity [43] the develop a computer database is very significant to enabling technologies in an exceedingly interconnected manufacturing system [44], which may be accomplished by improving solutions based on STEP and STEP-NC for the integration of CAD, CAPP, CAM, and CNC [45] which develops data exchangeability and utilization interoperability. A cloud-based system is utilized to store and display the data and the information to the user.

1.6 Global Aims in Smart Manufacturing Technology

Since the industrial revolution that started in the UK in the midst of the 18th century with the steam-engine improvement, through the mass production system in the early 19th century thanks to the commercialization of the electricity, and to the development of ICT (Information and communication technology) and the introduction of automation system in the late 20th century, the manufacturing industry has been building innovative advances that could possibly be called advanced. Currently, the advances in ICT technologies have frequently advanced in different areas, including H/W (hardware) and S/W (software), and may bring a renaissance or a new revolution to the manufacturing industry. Smart Manufacturing may have the driving the force of this new change.

It is a collection and a model of various technologies that can develop a strategic modification of the existing manufacturing industry through the convergence of humans, technology, and information. While lean manufacturing focused on cost saving through waste elimination during the 80s and 90s, Smart Manufacturing is a planned increase engine that aims for a sustainable growth via administration and enhancement of the existing major manufacturing parts, such as productivity, quality, distribution, and elasticity based on technology concentration and various elements over societies, humans, and habitat. NIST (National Institute of Standards and Technology), which is an agency of the U.S. Department of Commerce, defines Smart Manufacturing as "completely-combined and collaborative manufacturing systems that respond in real time to meet the growing demands and conditions in the factory, supply network, and customer needs. Advanced manufacturing countries, such as Germany and the U.S has already been improving technologies in different domains to achieve Smart Manufacturing over the past few years.

The major technologies are IoT (Internet of Things), CPS (Cyber-Physical System), cloud, etc. These technologies were developed as cutting-edge ICT technologies and they have been applied to various fields such as manufacturing, energy, construction management, etc. Smart Manufacturing can be strongly achieved through a balanced improvement and application of those major key technologies. [46] The German government stated Industry 4.0 to establish smart companies that are the ultimate achievement of Smart Manufacturing, and it is a mixed project including the special sector, government, and academia. The Industry 4.0 concept was first published at the 'Hannover Messe 2011' that was held in Germany. The final report on Industry 4.0 specified that it generates new states that have not been seen before, creates new business models, and proposes various social problems by connecting the things inside and outside a factory and services through the communication networks based on CPS, IoT, and IoS (Internet of Services).

1.7 Big Data for new Industry

We are living in a period of data deluge and as a result, the term big data'' is emerging in many settings, from meteorology, genomics, complicated physics simulations, physiological and environmental research, investment and industry to healthcare. One interesting example is that a press release of SAP AG, dated 11 June 2014 reported, ''SAP and the German Football Association turn big data into smart decisions to improve player performance at the World Cup in Brazil.'' An International Data Corporation (IDC) report [47] predicts that ''from 2005 to 2020, the digital universe will improve by a factor of 300, from 130 Exabyte to 40 000 Exabyte'' and that ''from now until 2020 will about double every two years.'' As the name indicates, big data really means huge collections of data sets including rich information. However, it has some special features that distinguish it from ''very large data'' or ''large data'' that are simply enormous collections of simple-format records, typically equal to large spreadsheets.

Big data, being frequently disorganized and heterogeneous, is remarkably complex to deal with via traditional programs, and requires real-time or almost real-time analysis. A short definition can, therefore, be that ‘‘big data’’ refers to data sets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse. For a thorough analysis of various features of big data and the difficulties it performs, together with some possible research directions, the reader is referred to [48].

1.8 Developing Importance of big data in industry

For new industry, data produced by machines and devices, cloud-based resolutions, business administration, etc., has reached a total volume of more than 1000 Exabytes annually and is expected to increase 20-fold in the next ten years. McKinsey & Company reports that ‘‘manufacturing markets more data than any other sector close to 2 Exabyte of new data stored in 2010’’ [49]. for example, in a consumer-packaged-goods business that provides a personal care product, a single machine alone generates 5000 data samples every 33 Ms, occurring in four trillion (i.e., 4 Tera) samples per year [50]. From an industry point of view, big data is moving to play a significant role in the fourth industrial revolution [51].

The purpose is to understand smart factories, in which machines and devices communicate as in a common network. Such a smart factory will create intelligent products that know how they have been produced, and will collect and transmit data as they are being utilized; these large amounts of data (big data) will be collected and analysed in real time. New shrewdness will thus be produced and utilized to advance one level up from smart factories to smart processes, and finally, to the level at which intelligent services can be given to the consumer through internet-based services. The main goal behind the use of big data in industrial applications is to produce a fault-free and cost-efficient running of the process, while realizing the coveted performance levels, especially with respect to quality.

McKinsey proposes that businesses could make up for a 50% reduction in product improvement and construction costs, and up to a 7% reduction in the working industry through the use of big data. At a bigger level, the data sent by the smart devices can help the company to pinpoint the favourites of the customers and, thus, shape future products. Process engineers, instead of working with a mechanical model of the system (which may be very complex, if not impossible to drive), favour a model-free approach and use advanced systems to control, monitor, and optimize the performance of the process, based only on a lot of measurements.

Suitable acquisition and analysis of big data have the potential to improve the product with a resulting competitiveness in a wide range of industrial sectors. From the point of view of manufacturing engineers, supplies chain administration can be improved via big data solutions [52]. Additionally, by the individual analysis of big data, more effective risk control systems can be designed to help company management to make better-informed choices and develop corporate governance [53]. Based on these comments, it is apparent that significant research focusing on big data solution is important and critical for our life and especially for the future industrial applications.

CHAPTER 2

GLOBAL SCENARIOS

2.1 Introduction

The world today stands at the threshold of a new revolution, the fourth in the history of mankind. The World Davos Forum has chosen the title "Fourth Industrial Revolution" as the theme of its 46th session, The reason for this choice, according to the experts that "the Industrial Revolution 3.0", a digital computing revolution, which began in the fifties of the last century, and reached its peak and its applications in artificial intelligence, biotechnology, three-dimensional revolution taking place in the field of social networking and digital world sites.

2.2 Revolution waves

Participants at the Davos industrial revolution described the tsunami as a fourth technological advances that will change in many of the details of human life. Some expressed concern about this digital revolution, and the role of the citizen in the digital space interaction as distinct from the traditional social interaction, digital interaction has become a tool available to all, as well as the fact that electronic spaces became easy access after it was distant or excluded.

The concept of the Fourth Industrial Revolution, which was started by Germany, which is identified to the automation of the industry and the reduction of the number of labour in it. The human role in the industry is constrained to observing and evaluating. However, the great advantages that are "revolution" can bring to the benefit of humankind are balanced by the negative impacts that social orders will have on them, including the societies of the developed countries.

At present, the Fourth Industrial Revolution, Based on concrete electronic production systems that aim to link global production to real and virtual, the Fourth Industrial Revolution / digital processes combine digital conversions and integration of value chains and products / services. In addition, information technology, machinery and human beings are interrelated and interact in real time, creating a custom, flexible, resource-efficient manufacturing method that is equivalent to the smart factory that uses the Internet to do things at work.

2.3 Manufacturing sector in Singapore

Manufacturing sector in Singapore's continues to face phenomenal difficulties amid global economic headwinds. Hence, the time is ready for an all-encompassing redo of its manufacturing sector to receive the full rewards of Industry 4.0, while proactively dealing with the challenges and disengagements made by this noteworthy progress.

Growth story Singapore since independence, and continuously the Ministry of Manpower turns to develop a workforce able to compete globally for Singapore, to build a progressive workplace and to ensure financial security and staffing over the life of all Singaporeans [54]. In view of the manufacturing sector's strong backward linkages to the services sector, efforts to grow highly-productive modern services under the Government's Industry Transformation Maps will be supported by the concomitant development of a globally-competitive manufacturing sector [55].

2.3.1 Significantly Contributes to Overall Productivity Growth

The manufacturing sector working around 510,000 specialists in December 2015. While employment in the sector has seen a decline in recent quarters due to global economic conditions slow more compact than foreign labour and the provision of, and out of the average income of the local population in the region to grow. In 2015, the average monthly nominal income of the population increased full-time workers in the sector raised by 5.4 per cent, from 4104 dollars in 2014 to US $ 437 4 United States dollars. Over a period of 6 years longer than in 2009 to 2015, the average monthly nominal income of the population employed rose full-time in the sector by 5.5 per cent on the basis of an annual compound, which is higher than the annual growth rate of 5.1 per cent for staff full-time residents of the macroeconomic shown in Figure 2.1 [56].

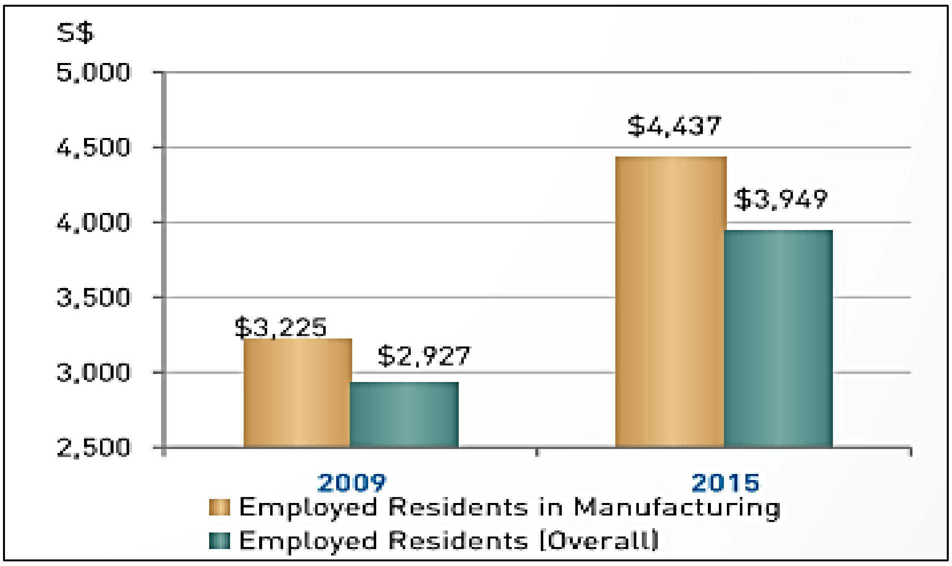

Figure 2.1 Median Gross Monthly Income for Full-time Employed Resident [56]

2.3.2 Manufacturing Can Generates Positive Spill over to the Rest of the Economy

The results in the manufacturing sector is also the indirect effects of health for the rest of the economy, given that various intermediate inputs such as distribution services, transportation, finance and what is required in the production process. By utilizing the input-output tables in Singapore, and is estimated to be S $ 1000000 increase in the final demand for manufacturing generates S $ 81000 from VA and non-manufacturer-.65 work non-industrial opportunities, and especially benefit the wholesale trade sector. Relatively, and S $ 1000000 increase in the final demand for services generates $ 22,000 of S non-VA services and non .27 services jobs[56].

2.3.3 Electronics

The electronics industry in Singapore since 2012 is the backbone of the manufacturing sector, contributing to the countries by 5.2% (GDP). , Where it supports Singapore's economic growth, by contributing 25% of total value added production. On the other hand, total fixed assets investments reached 16 billion dollars in 2012, with the percentage of electronics industry about 38.8% of total investments. The number of factory workers is about 80,000, which is 19% of total manufacturing jobs. Which accounts for almost 20% of the mass electronics and semiconductors representing the largest and fastest-growing sector and competing with countries such as Japan, South Korea, Taiwan, the United States and China in terms of chip production capacity [57]. Singapore has become one of its three largest economies of the world in the region, which is one of the major players in the free trade agreement (FTA) activity. Enhancement, ASEAN as a group is developing as the centrepiece of the Asia Free Trade Agreement (FTA) package. In contrast, it has maintained Asian free trade agreements through strong regional, trade coverage increased free trade agreements, and other issues of trade liberalization such as investment, intellectual property rights, labour standards or mobility has been included [58].

2.4 Manufacturing Sector in UK

Manufacturing sector in the UK with statistics in 2016 has been accounted for 8% of jobs, while 2.7 million in total UK of 10% and the output economic of £177 billion. Hence, 57% of imports, which worth £243 billion and 70% (£15 billion) of UK research and the development has spending shown in Figure 2.2[59].

Figure 2.2 Manufacturing as a Percentage of UK total: Output, jobs, R&D and exports [59]

2.4.1 Impact of the 2008-09 Recession

The manufacturing sector has not recovered to the pre-crisis level. The initial recovery in manufacturing output stalled in early 2011 and declined for the following two years. In early

2013 a more sustained recovery began and between Q1 2013 and Q3 2017 manufacturing output grew by 7%. However, manufacturing output is still 2% below its recent peak in Q1 2008 [59].

2.4.2 Manufacturing in Various Industries

In The Figure 2.3below demonstrates the various industries that make up the manufacturing sector. However, these industries share of total manufacturing output, Food manufacturing accounted for 16% of the manufacturing industry in 2016, while the manufacture of transport equipment which incorporates the automotive industry accounted for 15%, and the manufacture of metals and metal products accounted for 12% [59].

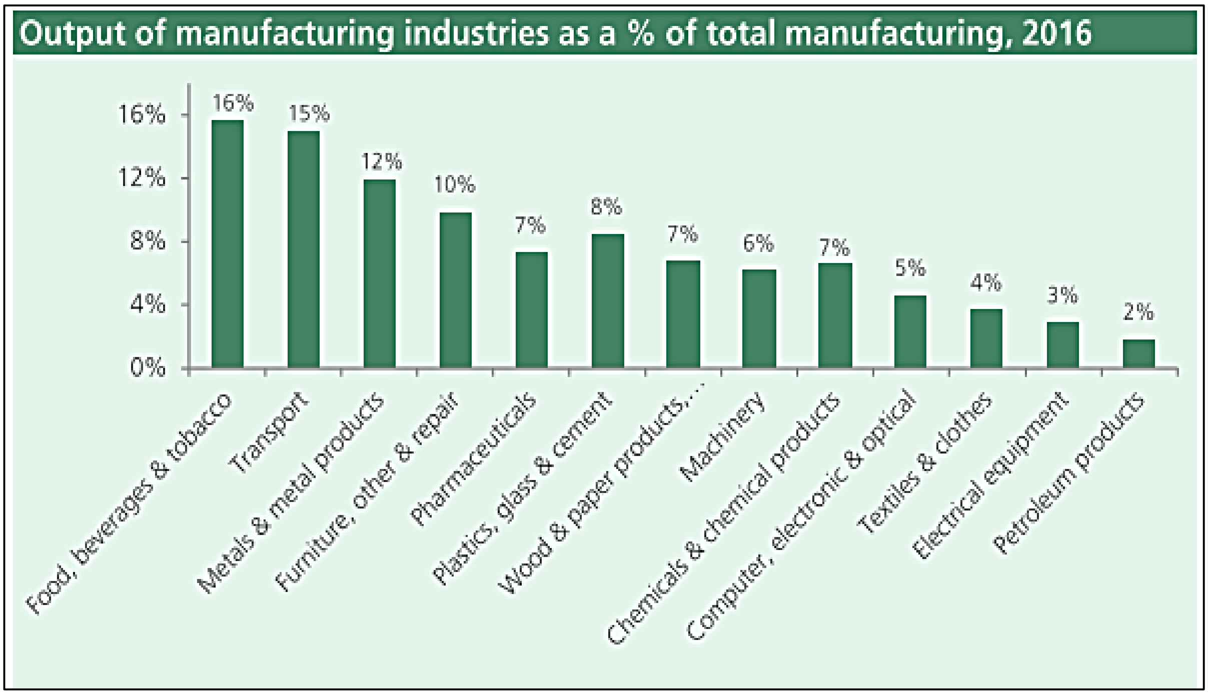

Figure 2.3 Output of Manufacturing Industries as a % of total Manufacturing, 2016 [59].

2.4.3 Manufacturing firms become service providers

The manufacturing companies have turned themselves into majority-owned companies in providing the service. One of the notable examples of IBM, which now considers itself primarily in the service business, and although it still makes computers. Production of material goods has become secondary to companies that focus instead on providing "business solutions". So the shift from manufacturing companies to service providers is part of a shift in the comparative advantage of the advanced economies [60].

In particular, it is the most recent survey of purchasing managers working in the employment growth industry in the UK manufacturing sector, has reached its highest level in more than three years. The survey also indicated that manufacturing companies were experiencing sharp increases in costs, which rose at their fastest rate in seven months [61].

2.5 Manufacturing Sector in EU

The European Union between the Future of Manufacturing Scenarios (2015-2020), providing creative images that are based on potential social and economic developments and future technologies that are likely to shape the European industrial sector in the coming years. Especially, scenarios that highlight important trends, challenges and potential critical trend breaks, opportunities and present four visions conceived industrialization in Europe in 2015-2020 [62].

The European Union has been informed of the relevant data and trends in the food and beverage industry in the 2016 edition, providing a comprehensive and general picture of the structure and economics of the food and drinks industry sector in Europe, which is one of the largest manufacturing industries in the European Union in terms of turnover of value added and employment [63].

2.5.1 Role of Industry

Europe is a worldwide pioneer in numerous industries which supply high-value employments, for instance the automotive, aeronautics, engineering, chemicals, energy solutions and pharmaceutical industries. Industry represents for over half of Europe's exports, around 65% of research and development investments, it provides more than 52 million occupations (through direct and indirect jobs, meaning 24% of jobs in Europe), generally high-skilled jobs and above average pay, and in high economic value added activities. Industry generates strong positive spill-overs on the economy. In certain countries, industrial front-runners generate 25% of all added-value through direct and indirect effects as show in Figure 2.4 [64].

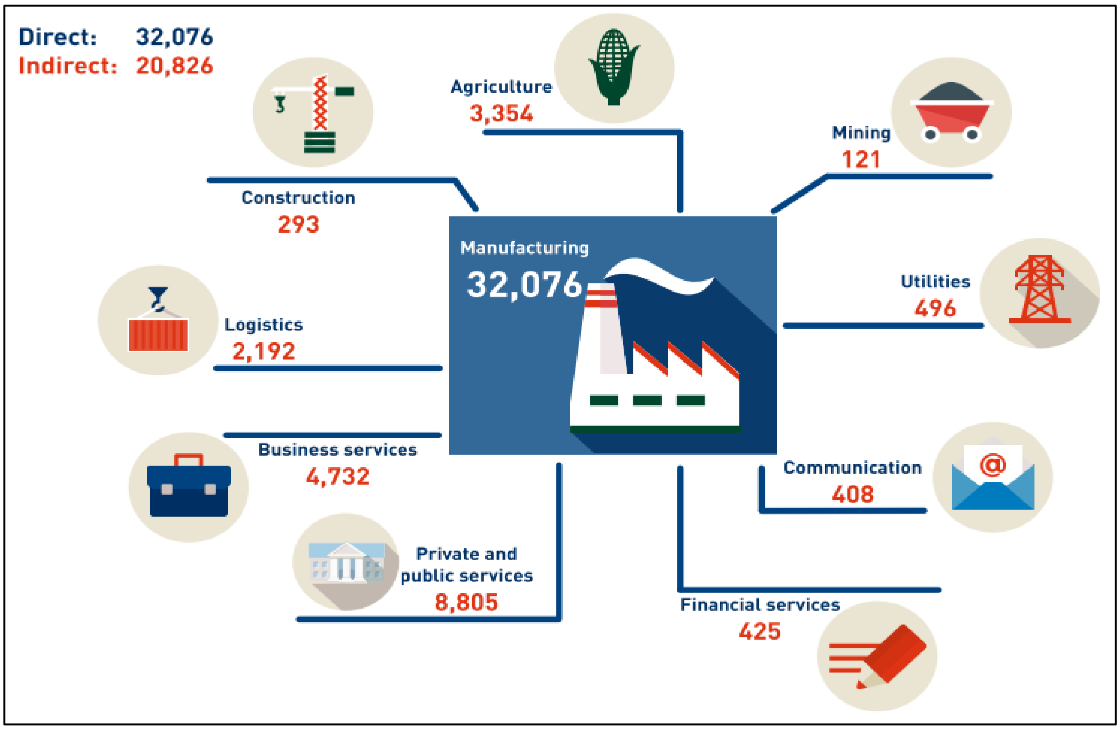

Figure 2.4 Direct and indirect employment in the manufacturing sector, 2016 [64].

2.5.2 Drivers and Challenges in European Manufacturing

The European manufacturing sector is likely to undergo drastic changes over the next two decades. On the other hand, this section paints the results of an in-depth discussion on the major drivers of industrialization in Europe that emerged from the scenario-building process for drivers and the difficulties that will likely reflect the future of industrialization in Europe. However, the technological, environmental, economic, political and social factors shaping the future of the industry may have an impact to accelerate the pace of development in the EU [62].

2.5.3 Estimation of Fixed and Variable Production Costs

Analysis and documentation at the corporate level suggest that multinational German companies still produce a significant share of global output in their home country, although the fact is that they are active in several other countries. However, the appreciation of the changing efficiency of foreign production and increase returns on the factory level of losses suggests that multinational companies described as inaccurate. Both differences in variable production costs across countries and fixed costs for the establishment of foreign stations have become important barriers to foreign production of multinational German companies [65].

2.6 Manufacturing Sector in USA

The manufacturing sector in the developing countries comes first and therefore continues to apply the conditions which it described as its engine of economic development. In order to achieve sustainable growth while maintaining the same size in the GDP, taking into consideration the total employment as in the period from 1970 to 1990 [66].

2.6.1 Why manufacturing matters

Presented to states and political systems, manufacturing is seen as a fundamentally significant and intense force of strong economic power. In the advanced economies, the strong manufacturing sector has to make the labour generously well-paid, and keep up with the specialized capacity; the shrinking manufacturing sector is evidence of the decline. Moreover, manufacturing is recognized as an engine of development, which raises the level of the agricultural population from poverty and transforms poor countries into actors in the world economy. Today, the global manufacturing sector is facing a series of changes and challenges stretching from the shift in demand to developing economies to new constraints on key inputs such as resources, energy, transportation [67].

2.6.2 Revitalizing Manufacturing in the United States

The United States has long prospered its ability to manufacture and sell goods in local and global markets. Where, it has supported the industrial activity of economic growth, leading to a rise in exports of the country, and the employment of millions of Americans. Yet throughout the 20th century, the US manufacturing sector led to an increase in the production of knowledge and innovation through the shift from R & D to products used worldwide [68].

2.6.3 Employment

In the United States, occupations are classified as an industrial function if they occur in a facility whose primary activity is production. Therefore, there is a clear situation for the employees who work in the factory that produces steel for use in cars. However, designers of manufactured products in a design company or warehouse workers assemble products manufactured prior to shipment not to be considered as manufacturing workers. Thus, the total number of full-time and part-time staff is now on the payroll of manufacturing enterprises. For the manufacturing sector in the United States, it claims to add jobs, but not at a very fast rate. In addition, the current level of employment of about 12.5 million workers is still well below the level of 18 million that existed before the recession period 2007-2009 [69].

2.6.4 Road-mapping

Power America released its second member-led Technology Roadmap 26 in May of 2016 in order to help U.S. created wide bandgap technologies reach their potential in reducing energy consumption and emissions in a variety of industries, while also creating manufacturing jobs across the United States. However, the roadmap proposes a unique strategy to make broadband semiconductor technologies very expensive to compete with silicon-based energy electronics while accelerating adoption of these technologies in new markets and applications. In addition, the roadmap thrusts improving reliability, reducing cost, enhancing performance capabilities, and strengthening the power electronics ecosystem form an integrated, collaborative strategy for advancing U.S. created power electronics technologies [68].

2.7 Manufacturing Sector in China

At the global level, there is still industrial output (as measured by gross value added) to boost its growth by 2.7 percent a year in advanced economies and 7.4 percent in large developing economies (between 2000 and 2007). However, the growth of the economies of China, India and Indonesia are in the early stages of global industrialization and in the world's 15 largest manufacturing economies, contributing to the sectors from 10% to 33% of the value added [67].

2.7.1 A latecomer to manufacturing automation

China has various organizations that have advanced capabilities and dominated competitive market conditions. When it contrasts with the giants of the West's leading industries, as well as Japan and South Korea, China's manufacturing base is currently enjoying an average level of development. For example, on average, Chinese companies are much less automated use where only 49 robots per 10,000 workers [70].

2.7.2 CM2025 vs Industry 4.0

China Manufacturing 2025 (CM2025) faces these continuing challenges in the overall global advancement of manufacturing and technology relentlessly. These first, second and third industrial revolutions have resulted in the development of mechanical production driven by water and steam power, the adoption of assembly lines to produce large quantities driven by electricity and the move towards automation through the utilization of electronics and information technology (IT), respectively. By increase the digitization of productive manufacturing with “cyber-physical systems". Thus, Mass data and cloud computing enable data exchange to be shared and analysed across entire industrial value chains, human-related networks and robots interact and work together [71].

CHAPTER 3

MALAYSIAN SCENARIOS

3.1 Malaysia scenario in manufacturing sector

Manufacturing sector playing an important role in the growth of economic around the world. The importance of the manufacturing sector to the economy is evidenced based on it contribution to the gross domestic product (GDP), external trade and create jobs. Besides that, Malaysia also proven that, this country contribute in the growth of economy based on manufacturing sector. This is based on Malaysia achievement through the transformation, from an economic Farm-based and Commodity to an economic Industry-based country. In the last 5 years, Malaysia contributes about 22% to the GDP. Because of the growth, Malaysia able to decrease unemployment by creating a numbers of job, attract other country to invest in Malaysia and also success to create business opportunities. Based on Figure 3.1, under the RMK-10, annual GDP growth of manufacturing sector was 4.8% while under RMK-11, the manufacturing sector is targeted to achieve annual GDP growth rate about 5.1% [72]. By comparing to both growth rate, Malaysia targeted to increase about 0.3 % of the GDP growth rate by to 2020.

Figure 3.2 shows example of SMEs ecommerce adoption. The eCommerce portal is use as a right place to get started on eCommerce journey. SMEs can get any information on their fingertips. The information that available in the portal such as guidance, training information, and eLearning Module. The portal serve solution globally.

Malaysia manufacturing sector can be divided into two, that are large manufacturing firm and small and medium enterprise (SMEs). The large manufacturing firm is seen to be aware of benefit and risk of adopting Industry 4.0 practices. Figure 3.2 until Figure 3.8 shows successful story on implementation of industry 4.0 approach.

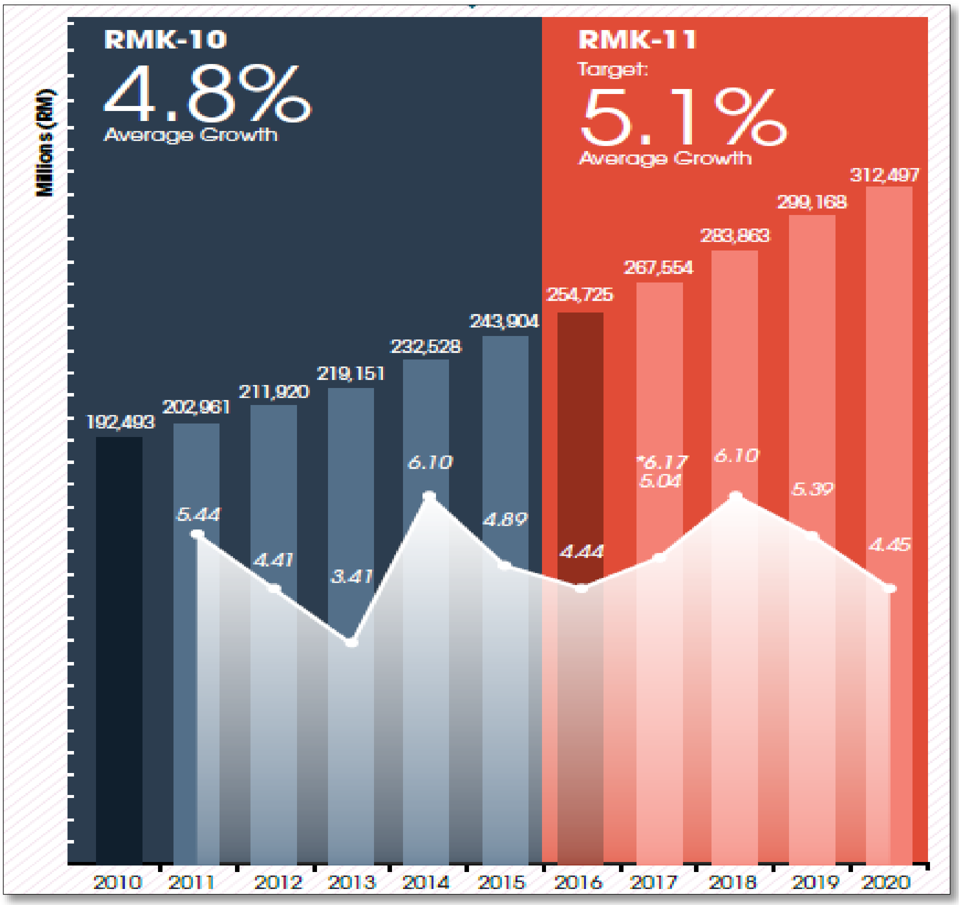

Figure 3.1 GDP contribution and growth of Malaysia's Manufacturing [73]

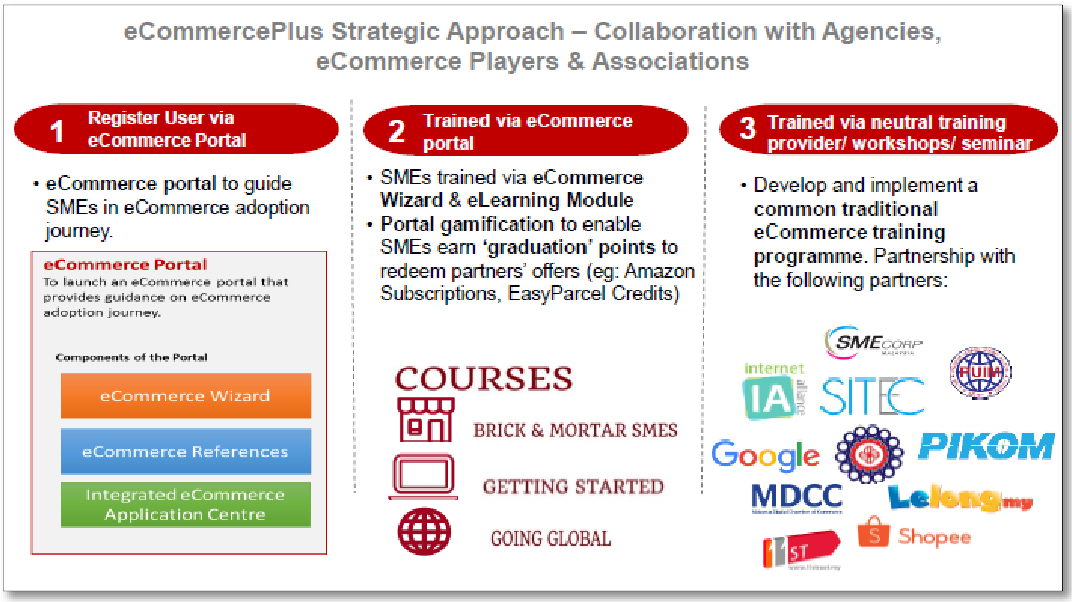

Figure 3.2 SMEs eCommerce adoption [72]

Figure 3.3shows world’s first digital free trade zone (DFTZ). The DFTZ is expected to increase SMEs growth rate of export goods double by 2025. It will be used in treading goods, services and regulatory processes. DFTZ act as regional eFulfillment centre and hub for SMEs, and many other trader. DFTZ is one of Malaysia effort to develop and nurture talent for driving digital innovation globally.

Figure 3.4 shows KLIA Aeropolis. KLIA Aeropolis is part of DFTZ initiative. KLIA Aeropolis is an effort of Malaysia Government to serve outsider a seamless blend leisure and business within the vicinity of Kuala Lumpur International Airport. Malaysia collaborate with Jack Ma’s Cainiao Network and Alibaba’s logistics arm to be the first electronic world trade platform hosts airport city. Malaysia Airport is transforming. From airport operator to ecosystem manager and integrated city.

Figure 3.3: World’s first digital free trade zone (DFTZ) [72]

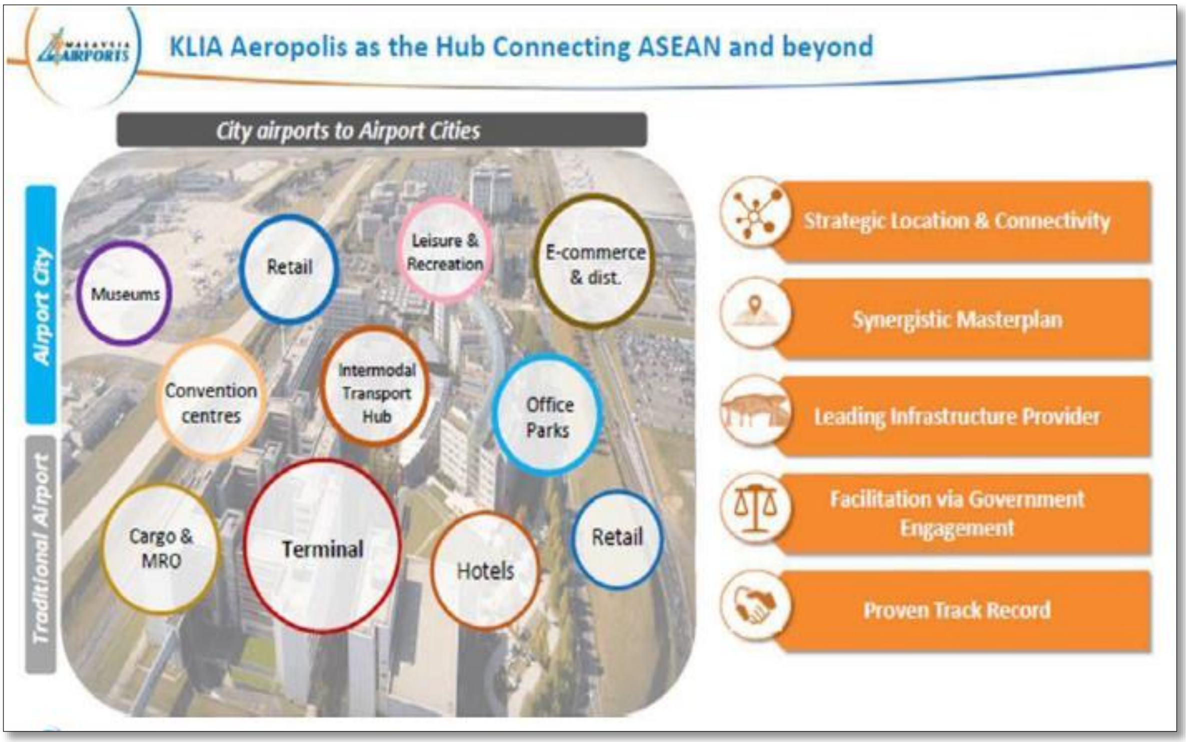

Figure 3.4: KLIA Aeropolis [72]

Figure 3.5 shows, STE Engineering Sdn Bhd. STE Engineering Sdn Bhd is a company that establish in May 2002. The company supply and manufactured Cable tray, Cable ladders and Cable trunking. The company adopt eCommerce approach by using Google AdWorks to market their product and services. By digitalizing the way the company marketing their product increase Sales more than double. This shows how digitalizing affecting growth in economy.

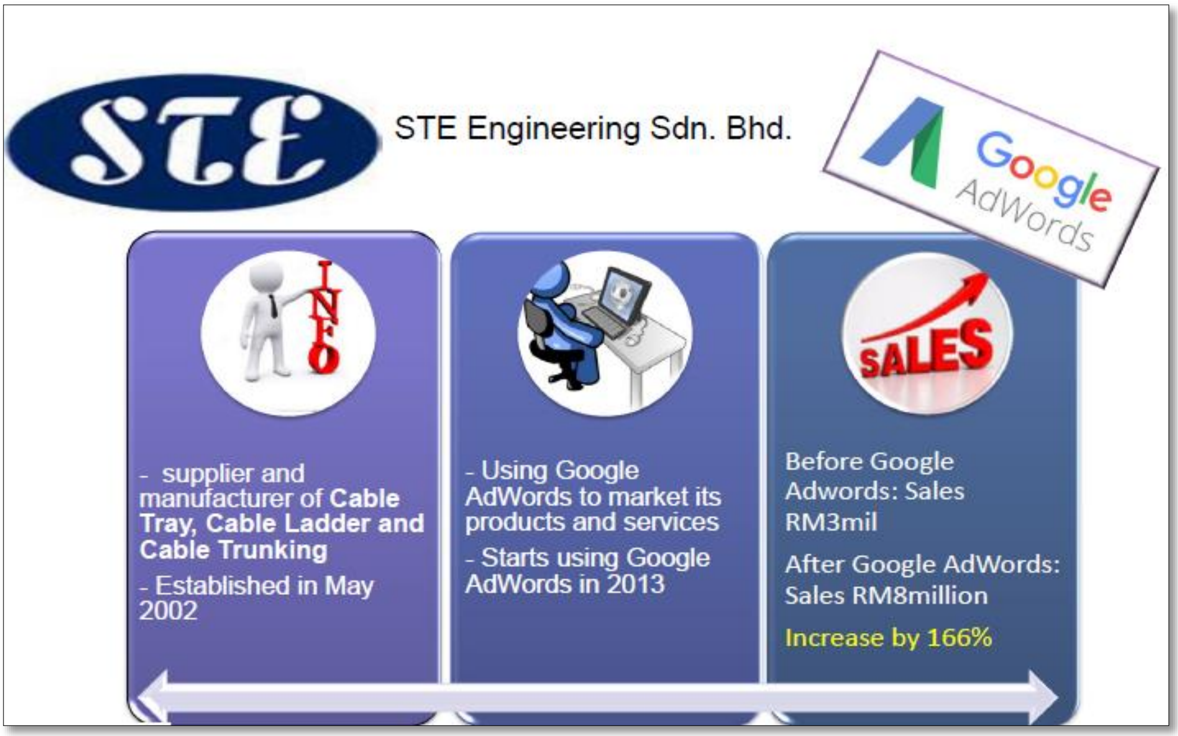

Figure 3.5: Adoption of e-commerce [72]

Figure 3.6 shows, 1-Innocert programme is a certification programme establish by SME Corporation Malaysia. SME Corporation Malaysia collaborate with SIRIM QAS International aim to promote and develop innovative companies in Malaysia. The programme is classify as an effort of Malaysian government to encourage SMEs Innovation development through application of science and technology. JF Microtechnology Sdn Bhd is certified with 1-InnoCERT triple A (AAA) rating and with score rating 4 Star based on their performance. The company core business are manufactured and trades electronic products and component. The company also export their product to US and Singapore. The company Annual sales also increasing year by year and this scenario contribute in the growth of Malaysia economy

Figure 3.6 : 1-Innocert programme [72]

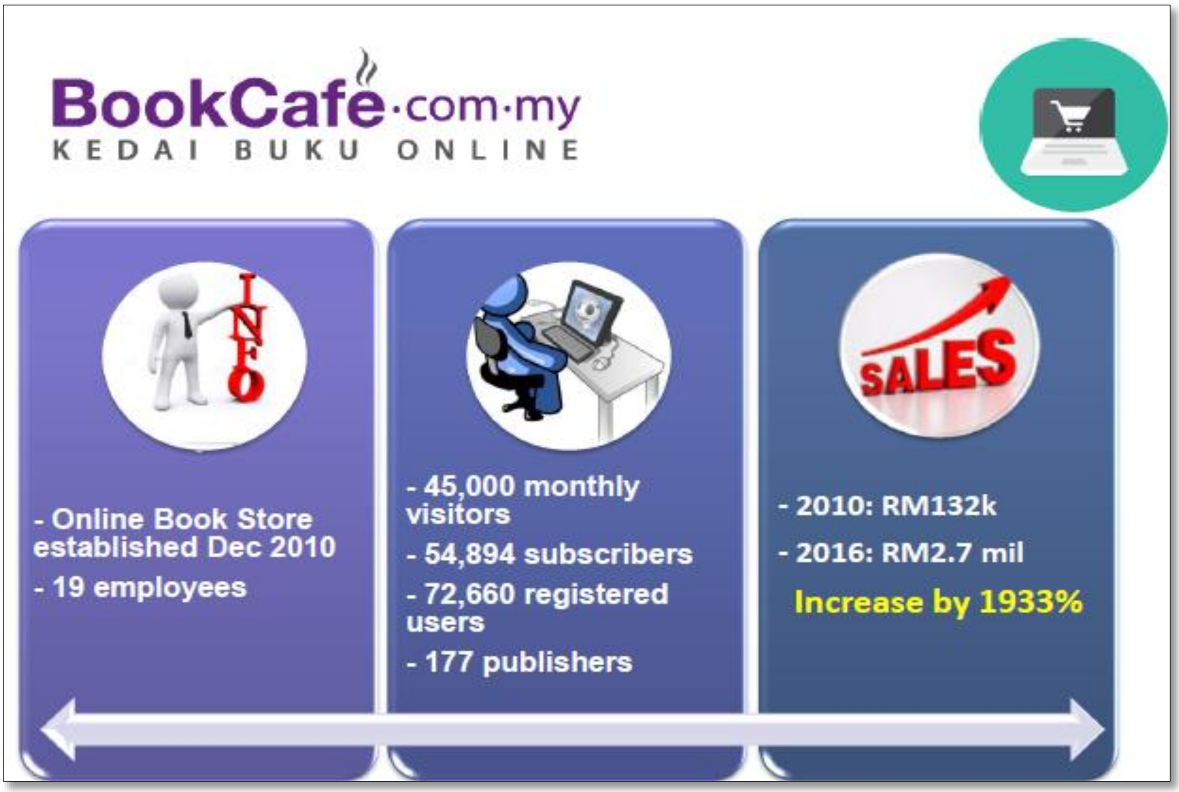

Figure 3.7: Adoption of e-Commerce [72]

Figure 3.7 shows e-Commerce adoption for selling books. The Online book store was establish in December 2010 with 19 employee. Based on this approach people all around the world would be able to buy books anywhere any time. Through digitalization, the book store sales increase from RM132K in 2010 to RM2.7 million in 2016. The increment is1933%.

Figure 3.8 shows AVIALITE the most successful company in Malaysia with innovative product and services evolution. Establish as Malaysia's first LED Aviation Obstruction Beacon and Warning Light in 2004. Winning award as Malaysia Company with strong research and development background. Continuously solving unsolved challenge through thoughtful design and perfecting lighting solution. Certified with 1-InnoCERT by SME Cooperation Malaysia and score rating 4 Star. Registered trademark in 7 countries.

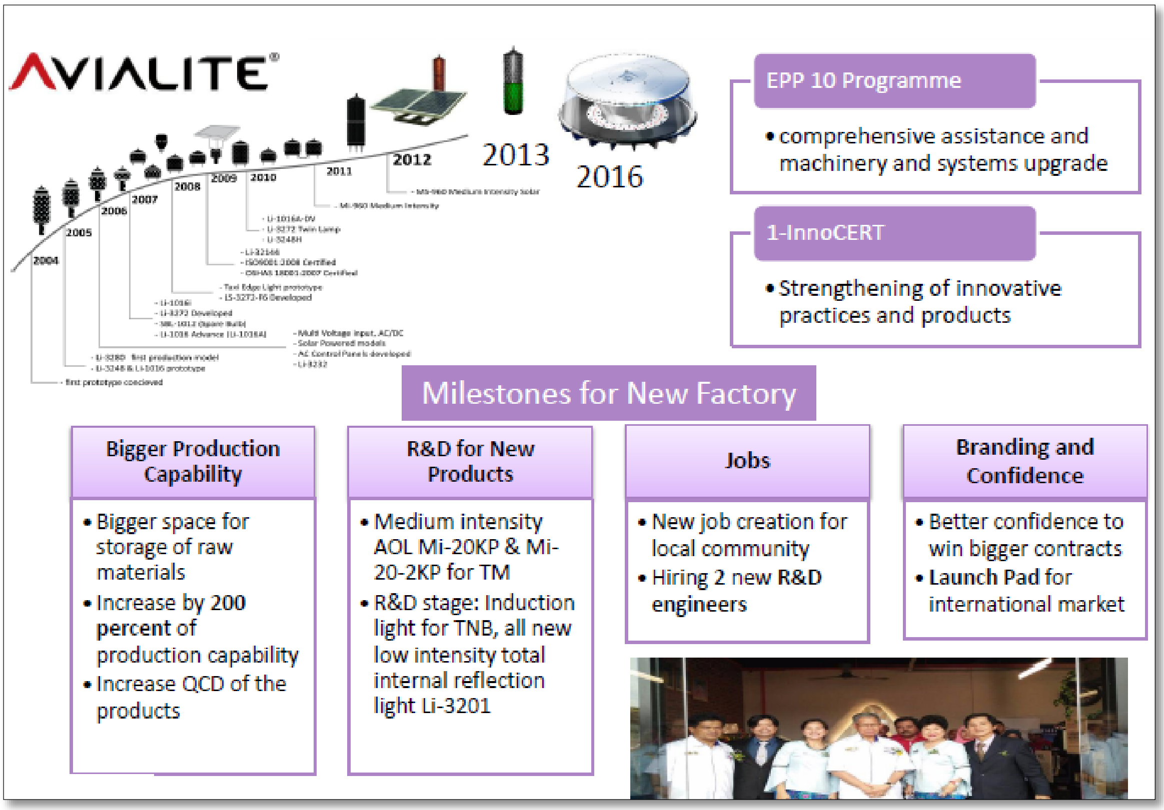

Figure 3.8: Innovative products and services evolution [72]

Even though there is successful implementation of Industry 4.0 approach in Malaysia, most SMEs do not aware about Industry 4.0. Based on a survey done by FMM-Malaysian Institute of Economic Research Business Conditions in 2H2016, about only 12% of the respondents are very aware of Industry 4.0. Other 88% include somewhat aware (41%), need more information (28%) and not aware at all about Industry 4.0(19%) [74]. This scenario seen to be very serious because Malaysia consists of huge number of SMEs and about 97% of Malaysia SMEs is a manufacturing firm [73].

Moreover, based on Malaysia standard classification of occupation 2013 reference by Economic Census 2016 shows that 42% of employment in Malaysia is covered by SMEs as illustrate in Figure 3.9 [73]. Furthermore, SMEs in Malaysia have the potential to be global exporters but weak in global presence. In term of readiness to adopt Industry 4.0, Malaysia SMEs still appear to be cautions in taking the leap. This cautions may give a risk and Malaysia SMEs might be left behind.

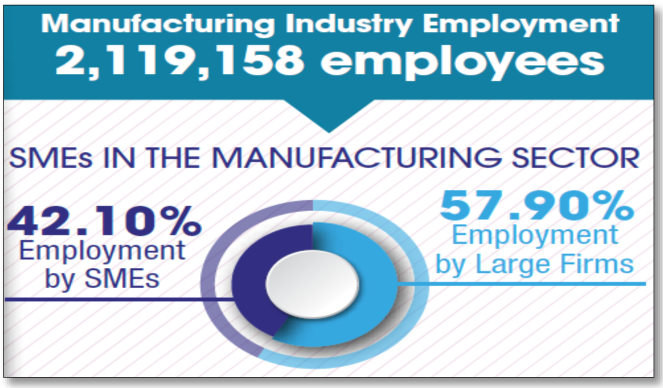

Figure 3.9: Percentage of employment by SMEs compared to large firm [73]

Adoption of Industry 4.0 in Malaysia manufacturing SMEs able to transform the SMEs in multi-ways. Industry 4.0 able to improve productivity, increase efficiency and decrease cost, enhance organization, management and increase capability of production, enable to improve quality and also enable to develop innovation. Beside number of employment, implementation of Industry 4.0 will required a knowledgeable and higher skill worker. This is due to the changes in the jobs landscape and also on the way of performing their jobs. The skill needed for the new job will be totally different from previous manual task. The changes in the employment landscape has significant implications for industry, education system and Government.

Figure 3.10 and Figure 3.11 showing a statistic on RMK-11 and MITI internal analysis in term of dependency of foreign labour and level of worker skill based on current Manufacturing scenario. The statistic shows that, Malaysia manufacturing sector is still depend on 26% of foreign labour and the skill of both Malaysian and non-Malaysian show that worker with high skill is only 18%, 75% semi skill and 7% with low skill. Moreover, only 7.5% worker with University degree and above, 12% with Diploma or STPM and 80.5% with SPM or SPMV or equivalent or below [73]. This scenario need to be transform to match with Industry 4.0 landscape and to increase productivity.

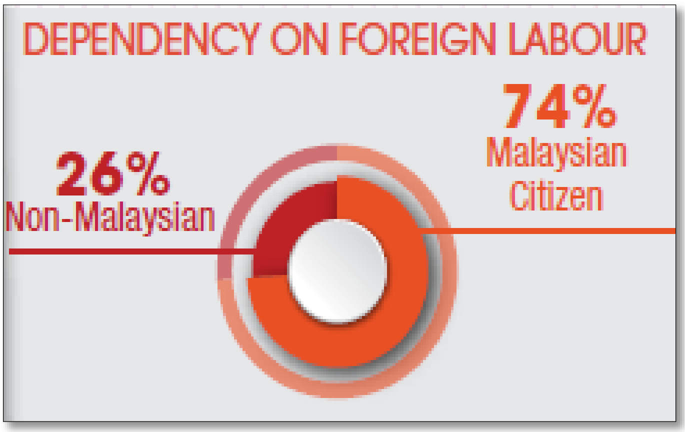

Figure 3.10: Percentage of Foreign and Malaysia labor [73]

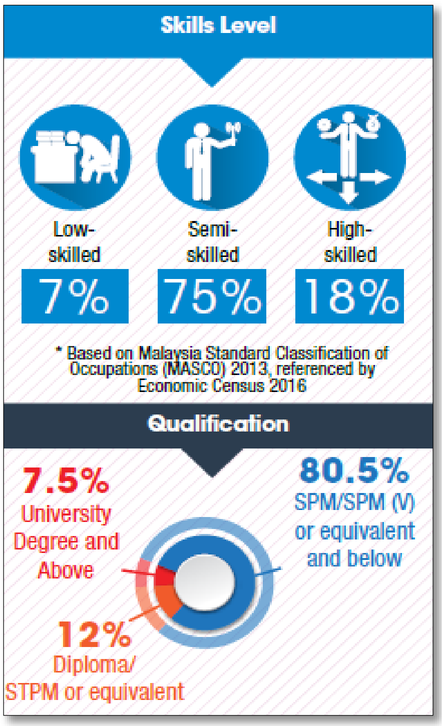

Figure 3.11: Skill level of Malaysia and foreign worker [73]

3.2 Government Role in Industry 4.0

To stay achieve the target of implementing Industry 4.0, Malaysia manufacturing industry need to be transform. Transform from second industrial era (mass production, assembly line and electricity) to fourth industrial era (cyber physical system). Transformation from manufacturing depend heavily on foreign labor to manufacturing based on local higher skilled labor and from low level of productivity to the high level of productivity. This only can be done by providing the right platform for the SMEs in Malaysia to reinvent and adopting the latest technology based on Fourth Industrial Revolution needs through Industry 4.0.

3.2.1 The National 4.0 Policy Framework

The world is currently in the midst of an innovation change that will fundamentally change the way people live and also affect economic activities and industries. It is somehow classify as a positive transformation. To realize the innovation changes in Malaysia, adoption of Industry 4.0 in Malaysia is crucial. On January 2017 the Government of Malaysia, had started to prepare a National policy or framework on Industry 4.0. A high level Task Force (HLTF) was led by Ministry of International Trade and Industry (MITI) with member from relevant Ministries and agencies to spearhead development of whole Government strategy for Industry 4.0 with stakeholder's feedback including from the industry.

The Industry 4.0 HLTF consist of five Technical Working Groups (TWGs) which includes digital Infrastructure and Eco-system led by KKMM, Funding and Incentives led by MOF, Talent and Human Capital led by MOHR and MOHE, Technology and Standards led by MOSTI and SMEs led by SME Corp. TWGs identify challenges, analyses existing gaps, propose action and recommendations to be included in the National Policy on Industry 4.0. MITI and its agencies in collaboration with relevant Ministries and Agencies are also undertaking various outreach programs to increase public/industry/academia/training institute's awareness on Industry 4.0. Two major outreach program were done nationally on 2 May 2017 and 15 June 2017 [75]. More outreach programs are in the planning stage including at the state and regional levels. The Government is also seeking feedback directly from stakeholders through various forums including one-to-one engagement sessions as well as online feedback through MITI's website. In May 2017, the Cabinet tasked MITI, MOSTI and MOHE to lead the adoption initiative.

The focus sector under the propose National Policy on Industry 4.0 is based on the current economic plan which are Third Industrial Master Plan (IMP3) and 11th Malaysia Plan (RMK11) [75]. IMP3 (2006-2020) identified 12 industries in the manufacturing sector for further development and promotion. Among them, six are non-resource based electrical and electronics, medical devices, textiles and apparel, machinery and equipment, metals and transport equipment and the rest are resource based industries petrochemicals, pharmaceuticals, wood-based, rubber-based, oil palm-based and food processing. While RMK11 (2016-2020) has identified 3 catalytic (Electric and Electronic, Machinery and Equipment, and Chemical) and 2 new growth (Aerospace and Medical Devices) known as 3+2 sector as a contributor to the manufacturing sector. 3+2 will be the focus sector together with other 4 sector that are automotive, petrochemicals, textile and services [75].

On 12 December 2017, the Ministry of International Trade and Industry, Datuk Seri Mustapha Mohamed announced that the blueprint for the National Industry 4.0 policy framework will be present by the first quarter of 2018. However, the draft of the National 4.0 Policy Framework [73] for public review is ready to be seen in the web page. From the draft, the current Malaysia vision for the manufacturing sector in the next 10 years is to be the strategic partner for smart manufacturing and services in Asia Pacific, Primary destination for high technology industry and total solution provider for advanced technology.

Besides that, the current National Goal also include in the draft. The National goals will be use as a guide and measures for the transformation progress. There are four aspects that are labour productivity growth, how far the manufacturing is contributed to Malaysia economy, innovation capacity and status of worker skilled. Moreover, the draft also includes the shift factor to be considered in the way of implementation Industry 4.0. There are three shift factor which are people, process and technology. It is important to optimize and balance between the three aspect by an appropriate approach and ecosystem. The reason to optimize and balance between the three aspects is that the adoption of industry 4.0 is based on how well the people, process and technology match each other. Another important aspect focus in the draft is the strategy enablers. The key enabler that will make the vision success known as F.I.R.S.T (funding, infrastructure, regulation, skill & talent and technologies).

3.2.2 Malaysia Ecosystem-Industry

Malaysia Government start to develop IoT Industry and Ecosystem through pilot Project. Four company in Malaysia is selected for the pilot project. ViTrox focus in Machinery and equipment, First solar focus on Electrical & Electronic, B BRAUN sharing Expertise focus on Medical Devices and DELLOYD Industries (M) Sdn Bhd focus on automotive parts and accessories. The focus area is based on the RMK-11 catalytic.

3.2.3 Malaysia Ecosystem-Training Institute

Implementation of Industry 4.0 required higher skilled worker. To full fill the need of highly skilled worker, in June 2014 the Malaysian-German Chamber of Commerce and Industry (MGCC) has implemented German Dual Vocational Training (DVT) program based on training standard of German. MGCC in cooperate with Department of Skills Development of the Ministry of Human Resources (MOHR), German-Malaysia Institute (GMI) and Penang Skills Development Centre (PSDC). The corporation between the four different departments is to upgrading skills of existing technical workforce.

3.2.4 Malaysia Ecosystem-Research and Technology Institute

Crest and AMIC (Aerospace Malaysia Innovation Centre) is two Research and Technology Institute launch as initiative of government of Malaysia to drive research and development activities in Malaysia. This two research and technology institute, affect positive change to the R&D ecosystem in the E&E Industry and Aerospace respectively. For a country to move and transform to Industry 4.0 continuously research and development is must.

3.2.5 Government Services Adoption

Another effort made by Government in adopting IoT in Malaysia are in the area of services. Three area of services include are IoT in Healthcare, 3Dprinting in pharmaceutical and Data management using BDA and cloud.

3.3 Issues

For as far back as 20 years, Malaysia's assembling area has set out on automated mechanical production systems, exactness designing and PC controlled procedures. Expanding upon the nation's solid assembling base, Malaysia is lining up with the Fourth Industrial Revolution (Industry 4.0) [76]. Being available to developing innovations is a key focused differentiator that will help with defeating the numerous difficulties looked by the present organizations. A key inquiry is the means by which how prepared Malaysia is for Industry 4.0. The current write about the Readiness for the Future of Production Report 2018, mutually distributed by the World Economic Forum (WEF) and A.T. Kearney, gives a worldwide appraisal of 100 nations and positions Malaysia in the "Leader" quadrant [73]. Industry 4.0 covers the entire value chain, including suppliers, procurement, design, logistics and even sales, resulting in higher productivity and flexibility [77].

The world is moving towards Industry 4.0, a process where the manufacturing process is digitalised and automated. As such, production will be accurate, eliminating human errors and improving consistency in the quality of products that can be produced in large quantities [74]. These are nations with a "solid current generation base" and who are "situated well for what's to come". It is likewise fascinating to take note of that Malaysia and China are the main two nations in the "Leader" quadrant, who are not high-wage nations [73]. This is both a fortunate and a testing position for Malaysia. From one viewpoint, it underscores Malaysia's solid current assembling position and its status for Industry 4.0. Then again, it additionally features the monetary incentive in question if Malaysia can't change itself in a quickened way.

China has its “Made in China 2025”, which has a broader scope to bridge the gaps and uneven matches between the quality and efficiency of its rising number of manufacturers. There is much confusion over these interconnected terms. What is clear, though, is the global acceptance of this significant technological advance. Sadly, Malaysia has been rather slow to embrace it, compared with Vietnam or Thailand which already have Industry 4.0 policy frameworks [77] . Industry 4.0 incorporates "the digitisation of the assembling area, with implanted sensors in for all intents and purposes all item parts and assembling gear", and constant examination of information amid the assembling procedure.

This change can possibly disturb "relatively every industry in each nation" and "is developing substantially quicker and with more prominent effect" than any of the past mechanical upheavals, as per the appraisal. What's more, "in a perpetually globalized world, Malaysia is constrained to grasp the fourth Industrial Revolution with a specific end goal to remain aggressive". Be that as it may, the country should be better arranged to stand up to the significant difficulties ahead [78]. The gap to worldwide leaders like Japan, Korea, Germany, Switzerland and China is as yet critical and other provincial nations like India, Indonesia, Singapore and Thailand have forceful plans and are moving quickly in their implementation [73].

A portion of the Malaysian organizations are now embraced innovative work, building outline, advancement and framework mix and creating restrictive apparatus and hardware for worldwide fares. To date, there are 165 ventures to make apply autonomy and computerization gear for different businesses. The vast majority of them are in particular hardware and gear for the semiconductor business and material taking care of while the rest are in sustenance and refreshments preparing and bundling. Add up to speculations made in these ventures added up to RM4.9 billion [76].WEF's examination distinguishes innovation, human capital, worldwide exchange and networks, and institutional structures as key drivers of generation for Industry 4.0. Malaysia's rankings in every one of these drivers stresses needs in innovation, human capital and institutional systems (21st to 30th position out of 100 nations) [73], reliable with a portion of the difficulties.

There are likewise in excess of 35 neighbourhood system integrators (SI) such as ACM, VisDynamics, Kobay Technology, ViTrox, Genetec, Greatech, RC Precision, Pentamaster and Keu Control that can give coordinated mechanized answers for cutting edge enterprises. The nearness of prestigious worldwide makers, for example, ABB, KUKA (provincial workplaces) and Hirata Engineering, which effectively create and deliver automated arms, have likewise prompted mechanical advance, aptitudes improvement and outsourcing necessities for this sub-segment [76]. The cost of adopting Industry 4.0 is the main reason for small and medium industries' hesitance.

Many prefer to keep their foreign workers, rather than to invest in automation and IT.As a result, Malaysia is regarded as stuck at the level of Industry 3.0 in terms of manufacturing technology. Minister in the Prime Minister's Department Datuk Seri Abdul Rahman Dahlan said 65% of jobs in Malaysia could be lost because of technological advancements. "We are unable to catch our breath because the world is moving at a fast pace with the digital economy," he was quoted as saying. According to Human Resources Development Fund (HRDF) chief executive Datuk C. M. Vignaesvaran Jeyandran, most of the 15 million Malaysian workers in the private sector need to be upskilled or trained to be multi-skilled to meet requirements under the increasing digitalisation of workplaces [77].

Malaysia's building supporting organizations have likewise been prepared to give reliable nature of generation and on-time conveyance. Innovation reception and dispersion are especially vital for SMEs and underscore the significance of making generation systems and coordinated efforts with MNCs and extensive organizations [73]. According to the FMM-Malaysian Institute of Economic Research Business Conditions Survey in 2H2016, only 12% of the respondents are very aware of Industry 4.0. About 41% are somewhat aware, 28% need more information and 19% are not aware at all [74].

Human capital concentration is critical to making a quickened move in efficiency, particularly as Malaysia has been depending on low work cost previously, with a declining offer of talented work reinforcing institutional systems supports the part of government in making the correct biological system and encouraging joint effort stages on worldwide exchange and venture, Malaysia is as of now all around incorporated into territorial esteem chains and shows a decent exchange framework, which is reflected in its solid worldwide positioning (seventh) [73].

3.3.1 Best practice understanding

Lack of a unified and effortlessly available data stage to see best practices and pertinent utilize cases. Few obvious examples of overcoming adversity of applying Industry 4.0 advancements and procedures by nearby organizations.

3.3.2 High Cost of Investment

Higher cost of selection and longer payback period for Industry 4.0 advances and procedures. Inadequate comprehension of costs versus advantages and capacity to lead Industry 4.0 business case examination.

3.3.3 Skill Enhancement

Limited comprehension of assembling firms of required future aptitudes and mastery and claim availability to leave on Industry 4.0 change. Significant lack of required abilities, aptitudes and information for Industry 4.0, especially in the territories of IoT, mechanical autonomy and AI.

3.3.4 Digital readiness & connectivity

Exposure to digital dangers with expanded availability and new advances, particularly IoT. Lack of coordinated and advanced way to deal with information assembling along assembling and supply chains. Low computerized selection particularly among SMEs (~20%) and constrained utilization of mechanization by assembling firms (lion's share of firms utilize under half of computerization).

3.3.5 Innovation

Ownership of Intellectual Properties due to between network and data sharing along the inventory network. Evolving client desires and interest for customisation of items and quicker conveyance speeds.

3.3.6 Awareness

Lack of mindfulness on the effect of and requirement for Industry 4.0 advancements, both regarding openings and plan of action disturbance, particularly among SMEs.

To guarantee the new strategy extensively addresses potential issues and difficulties looked by Malaysian assembling firms, a progression of industry and government office workshops were led, including a wide scope of partners. The issues are condensed in the accompanying, both on the request and on the supply side.

3.3.7 Infrastructure

Gaps in sending of fast broadband foundation in key mechanical and preparing areas and not generally ready to help Industry 4.0 innovation needs.

3.3.8 Standards & digital integration

Lack of clear norms for gear or frameworks that help neighbourhood and worldwide between operability of Industry 4.0 advances and procedures. Limited digitalization and computerized joining of key government organizations and procedures. Manufacturing and supply chains (e.g., a few confirmations, authorizing, custom clearances, endorsements, and so forth).

3.3.9 Training Providers

Education syllabus and instructional method for STEM related subjects not alluring and coordinated with industry needs. Limited engaging quality of assembling as vocation goal for top ability. Existing preparing programs not adequately designed for Industry 4.0 and current pool of coaches unfit to stay aware of the progression of innovation.

3.3.10 Ecosystem Support

Limited number of neighbourhood players giving Industry 4.0 arrangements crosswise over key innovations and not cost aggressive versus universal players. Limited joint effort and industry take-up of Industry 4.0 yields from colleges and research organizations. Shortage of specialists in the business, colleges and research organizations crosswise over most Industry 4.0 innovations. Insufficient neighbourhood abilities and limits in giving digital security arrangements that ensure Industry 4.0 applications.

3.3.11 Funding & Incentive

No particular budgetary help and motivating forces for Industry 4.0 innovation advancement, going from R&D, prototyping, testing, scaling up to redesigning offices. Existing, yet underutilized reserves for preparing and improvement and requirement for higher distribution for STEM instruction (e.g., grants).

3.3.12 Governance

Multiple, yet disengaged endeavours and restricted coordination among all partners in advancing toward a typical vision. No national stage and instrument to arrange projects and structure collective and adjusted methodologies for Industry 4.0 necessities.

3.4 Strategy

Government of Malaysia has planned few strategies to drive the county towards Industry 4.0 which covers every aspect of the development including economy, social and national agendas.

3.4.1 Funding and Outcome Based Incentives

It is the advancement and appropriation of Industry 4.0 innovations and procedures may require generous speculations by assembling firms. Inquiries will emerge on what motivating forces and financing alternatives are accessible by both Government offices and private elements, particularly for SMEs. The subsidizing techniques are gone for urging organizations to receive new assembling advancements and forms and put resources into R&D, particularly to create nearby arrangements focused at Malaysia's needs and needs. Extraordinary consideration will be given to cooperative endeavours in creating and sending Industry 4.0 advancements. To guarantee advance and effect, the motivating forces will be connected to particular results. These procedures are pertinent to both assembling firms as the clients and adopters and to specialist organizations of Industry 4.0 advances and arrangements.

3.4.2 Enabling Ecosystem & Efficient Digital Infrastructure Fast

Secure connection is an essential necessity for the acknowledgment of Industry 4.0. A decent and dependable web speed rate is required for actualizing web based creation advances or services, be it IoT arrangements, utilization of expanded reality and wearables underway, or the assessment of constant information. In spite of the fact that Malaysia has sent High Speed Broadband and 4G advancements on a far reaching premise, there are still a few holes in key modern and preparing areas. A digitalised and associated foundation crosswise over supply and assembling esteem anchors is basic to cultivate a consistent development of merchandise, information and administrations, drive productivity and asset enhancement, and bolster joint advancement endeavours [73].

As of now, various esteem chain components are still not to be digitalised crosswise over numerous services and offices, extending from different endorsement, authorizing, confirmation, to great freedom and different procedures Other initiatives already embarked on leading up to the overall Industry 4.0 concept includes the National Strategic Roadmap on Internet of Things, the Digital Free Trade Zone and framing 2017 as the year of the Internet Economy for Malaysia [74]. Specialist co-ops will assume a fundamental part in helping Malaysian organizations quicken their progress to Industry 4.0, especially in creating individuals, changing procedures and receiving advances. In that capacity, including specialist organizations and connecting them to assembling firms, particularly SMEs, is critical to make an all-encompassing and powerful Industry 4.0 biological community.

3.4.3 Regulatory Framework & Industry Adoption

Regulation is a key empowering influence of Malaysia's Industry 4.0 change. Exceptional accentuation should be on expanding the attention to the need and advantages of embracing Industry 4.0 innovations and procedures. This is especially vital for SMEs who still have a restricted comprehension of advanced and Industry 4.0 and regularly are worried about the cost and level of progress required. Also, to encourage a quickened change, instruments should be set up to enable assembling firms to comprehend their present abilities and what it will take for them to change and execute Industry 4.0 advancements and update procedures and aptitudes [73].

Information trustworthiness, security and investigation are another vital territory of centre to guarantee consistent information stream crosswise over esteem chains. This will likewise enable the Government to comprehend need issues crosswise over activities, services and organizations and, subsequently, can graph compelling projects and administrative help.

3.4.4 Upskilling Existing and Producing Future Talents

It covers the Industry 4.0 which is in a general sense reshaping the occupations scene and will encourage huge changes in how modern specialist play out their employments. Altogether new employments with altogether different expertise necessities will be made, while others, particularly manual undertakings, will wind up out of date. The moving business scene has critical ramifications for industry, training frameworks, and the Government. To help change the mind set, the National Press Club, Malaysia, is organising a seven-day Industry 4.0 and Digitalisation Study Programme in Germany in collaboration with HDRF, human capital solutions provider K-Pintar Sdn Bhd and the European School of Management and Technology based in Berlin. The first batch, comprising 25 members of the media, will be exposed to the technological changes through a combination of classroom sessions and hands-on visits to companies adopting Industry 4.0 systems [77].

A qualified and gifted workforce is essential for the presentation and reception of Industry 4.0. The specialized learning required is high, and will be essentially enlisted from the STEM (science, innovation, building, arithmetic) subjects. Be that as it may, for a few years the number of STEM graduates has fallen underneath desires. There is an earnest need to make a gifted and various workforce, with high pay, both by up-skilling the current work pool and by drawing in and creating future ability in the assembling division [73]. Specific consideration likewise should be given to re-skilling and re-conveying lesser talented labourers to different segments and exercises. Although the need to train the workforce is obvious, so far only two million workers of HDRF-registered firms have benefited from the agency’s training initiatives, such as the Industry Based Certification Programme. Over the next three years, HRDF is expected to spend RM203mil for training programmes in ICT adoption, big data, and empowerment of women and development of digital talent for industries. With the rapid changes taking place, a massive change in the education system is crucial. Based on 2015 figures, only half of Malaysian graduates are employed after leaving university, while a quarter remain jobless for six months or more [77].

3.4.5 Access to Smart Technologies and Standards

It is critical for comprehension of and access to cutting edge, financially savvy and interoperable Industry 4.0 innovations are at the center of opening the capability of Industry 4.0. At exhibit, the lion's share of Malaysian assembling firms studied receive under half mechanization. The encounters from different nations show the significance of advanced/innovation labs and community oriented stages, particularly open private associations (PPP), in spreading Industry 4.0 advances and exchanging learning. The Government plans to work with worldwide and nearby industry majors to set up advanced and Industry 4.0 showing and coordinated effort labs.

In addition, models consistence that encourages interoperability of frameworks, both broadly and universally, is imperative to help consistent esteem chains, upgrade assets, and enhance efficiency. At last, creating and commercializing new advances and procedures that address particular needs in need areas will be essential to hold Malaysia's situation as a favoured innovative and assembling center point and production network accomplice [73].

CHAPTER 4

FRAMEWORK AND INDUSTRY 4.0 CASE STUDIES

4.1 IR4 in the construction of industrial digital institutions

Manufacturing industries play an essential role in the ever-expanding world economy, accounting for 17% of the world's gross domestic product over the past 5-10 years. By entering a new era in which emerging technologies and digital strategies are changing our lifestyle, our business environment, additionally, the development of new technology and its applications is working on changing the way companies work internally and with clients. This issue influences the entire industrial system all over the world.

4.2 Digital transformation and integration of vertical and horizontal value chains

The Fourth Industrial Revolution is transforming the process digitally and vertically integrated into the entire enterprise, starting with the development Product and purchase, to manufacturing processes and services Logistics, service delivery. It also prepares all data operations Operation, process efficiency, and quality management, in addition to Process planning is available in real time and supported Enhanced reality, and improved within an incorporated network. In conjunction, the horizontal integration extends beyond the internal processes; Ranging from suppliers through to clients and all chain partners the value. It additionally, includes all techniques that vary between devices tracking and tracing, and integrated planning processes and implementation Real time.

4.3 Digital transformation in products and services

Digital product conversion involves expanding existing products, such as adding smart sensors or communication devices that can be utilized with data analysis tools, as well as creating new digital products focused on delivering integrated solutions. Organizations will be capable, through the integration of new roads for data collection and analysis of data generation in how to use product and improve products to meet demand growing from end-customers.

4.4 CNC overview

Computer numerical control (CNC) devices are the brains of machine tools used in all manufacturing industries. Since the 1950s, CNCs have gone through several generations, following the state-of-the-art computational platforms. The way of their programming, however, remains almost unchanged. The low level G-code programming language is still used in most of the CNCs. The G-code language was designed in the era when paper tape was the medium for moving data between computers and CNC systems. Today an average microprocessor can easily process complex three-dimensional data, and CNC machining is the only operation in the design-to-manufacturing pipeline that is not using full-fidelity product and process information [79]. Figure 4.1 shows the example of current CNC machine from Kent Industrial [80].

Figure 4.1 : CNC Machine [81]

CNC machine plays an important role in the growth of manufacturing world since its development. CNC technology uses computers and Computer Aided Design (CAD)/Computer Aided Manufacturing (CAM) software for the generation, parsing and execution of the sequential control. CAD is used to aid in the creation, modification, analysis, or optimization of a design [82]. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

Meanwhile, CAM is a subsequent computer-aided process after CAD. CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation and storage [83]. The CAM system adds cutting strategies, tools and operation sequence information into CAD file which will integrate the CAD/CAM system for further manufacturing process. However, there is a close gap between CAD and CAM, that can be filled with Computer Aided Process Planning (CAPP) [84] as shown on Figure 4.2.

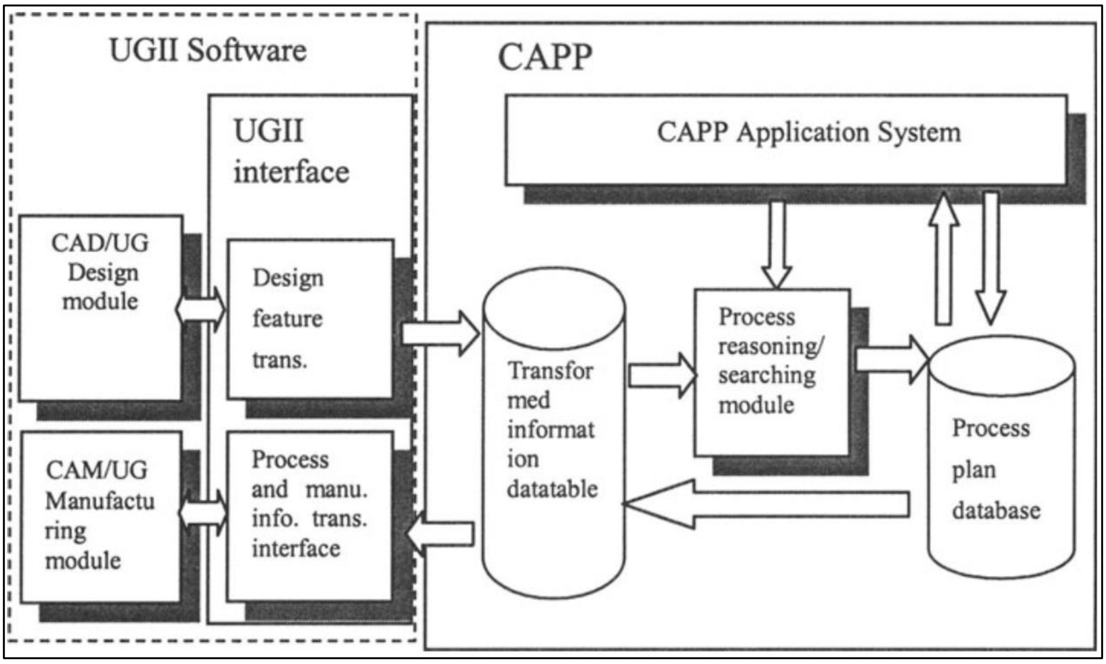

Figure 4.2 : CAD/CAM/CAPP integration architecture [84]

Computer-aided process planning (CAPP) is the application of the computer to assist process planners in the planning functions. It is considered as the key technology for computer-aided design (CAD) and computer- aided manufacturing (CAM) integration [85]. Basically the manufacturing cycle of manufacturing which includes CAPP is shown on Figure 4.3.

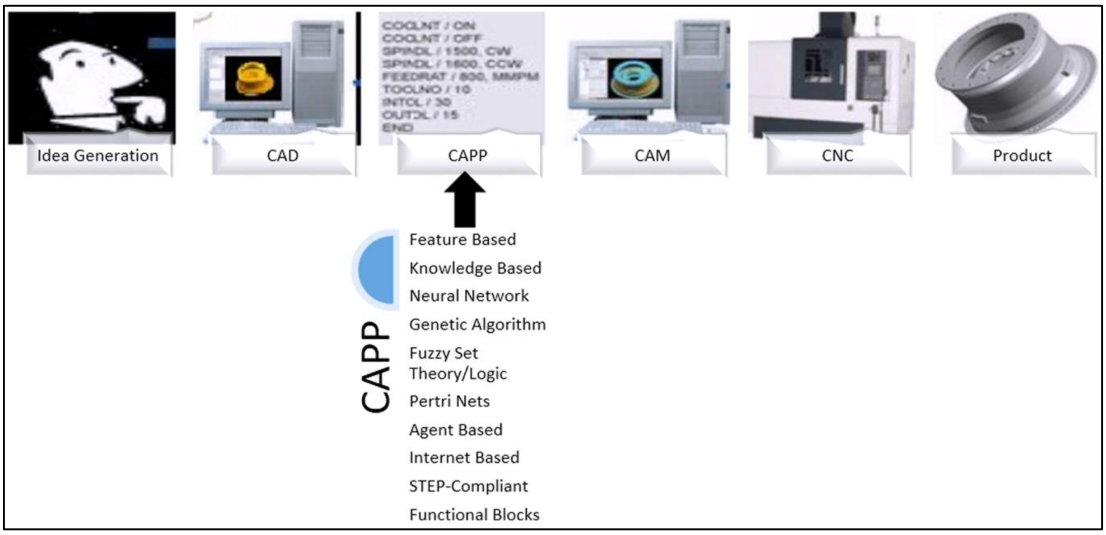

Figure 4.3 : Use of CAPP in manufacturing cycle [86]

CAPP then translates the CAD design specifications such as selection of raw material, manufacturing operation and machining operation condition into manufacturing information [87]. Later, the post processor of CAM system gives the manufacturing instructions for machine tool from CAM file [88], which translated to NC file on a specific language which first known as Automatically Programmed Tool (APT) [89]. In 1982, APT was adopted by ISO as an international standard ISO6983 which also formally known as RS-274D and commonly known as G M codes [90].

4.5 ISO 6983

The majority of CNC machines are programmed in ISO defined by just numerical codes such as G, T, M, F, S etc stipulating the movement of a machine and an axis to the controller, formally known as G&M codes language [90] which is then revised in year 2009 to ISO 6983-1:2009 [91]. The ISO 6983 standard focuses on programming the path of the cutter centre location (CL) with respect to the machine axes, rather than the machining tasks with respect to the part [92]. Thus, ISO 6983 defines the syntax of program statements, but mostly leaves the semantics ambiguous, together with low-level limited control over program execution.

These programs, when processed in a CAM system by a machine-specific post-processor, become machine-dependent [93] . However, this language brings only limited information to the CNC, this makes the CNC nothing but an executing mechanism which is completely unaware from the motions being executed. For ISO 6983, it has also become necessary to perform so called post-processing in order to convert the neutral part program for each controller [94]. CNCs which accept programs only in their proprietary versions of G-code, hinders the flexibility of manufacturing processes, especially within extended global enterprises.

In order to manufacture a certain product on a certain manufacturing site, the company may need to pass on their full information, database and data model of the product. The G-code programming defines the instructions of where , how and what path to take based on five specifications of coding from [90] shown on Figure 4.4 and explained in Figure 4.5 which shows the signs and functions for each commands specification.

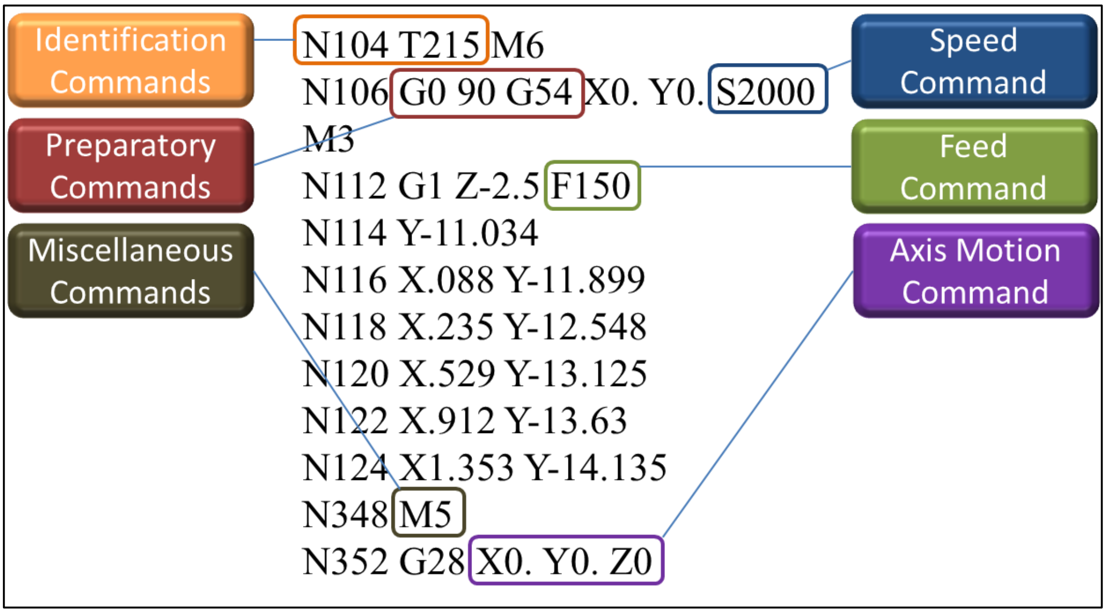

Figure 4.4 : Coding based on IS0 6983 [90]

Significant improvements are achieved due to introduction of minicomputers and microcomputers, where the capabilities of CNC machine tool especially in multi axis, multi tool and multi processes are increased [95] . Nonetheless, the need for programming became more complicated and difficult with the advancement towards flexible manufacturing environment. Hence, flexible manufacturing is targeting for CNC systems that are more adaptable, open, interoperable, intelligent and network portable [96].

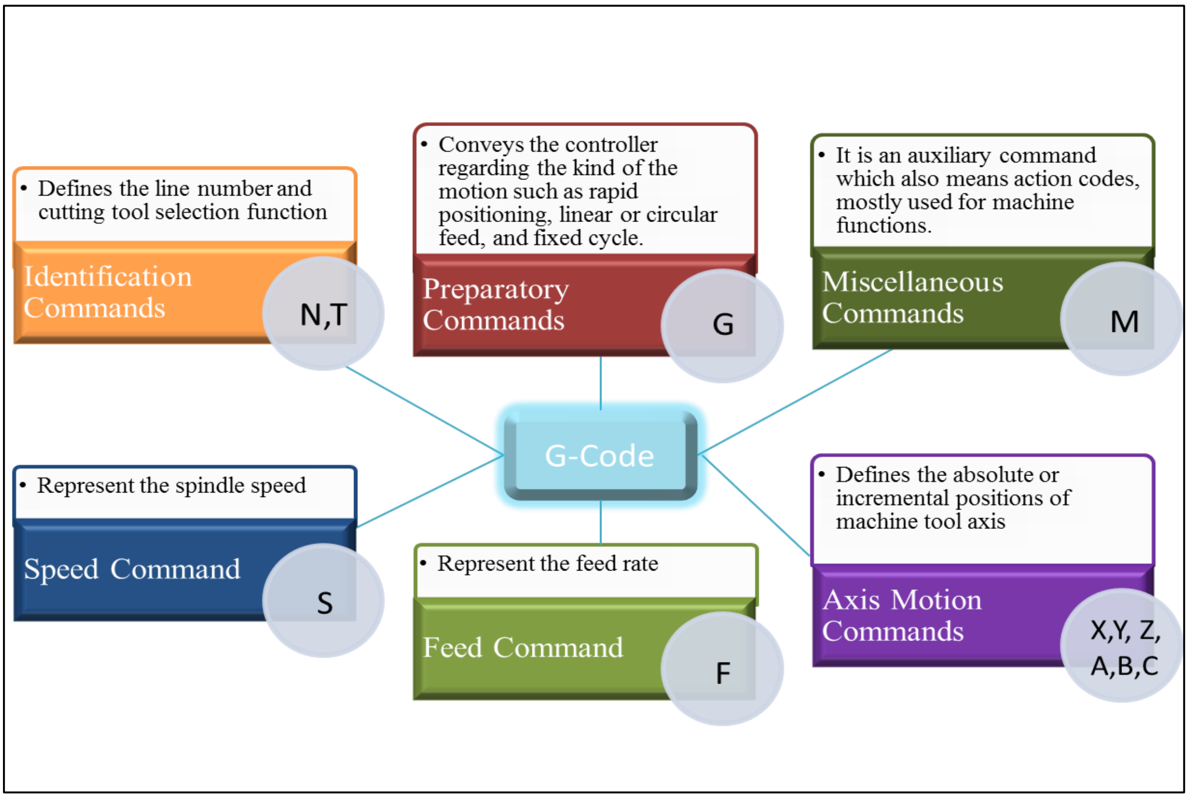

Figure 4.5 : G-code coding specifications, signs and functions

4.6 ISO 10303

ISO 10303 commonly known as Standard for the Exchange of Product Data model is acronym for STEP [97]. The objective of STEP is to provide a neutral mechanism capable of describing product data throughout system which independent form any particular computer system [98] with creation of single standard which covers all aspect of CAD/CAM data exchange with the implementation and acceptance by industry [99]. Product data represents information for communication, interpretation or processing by human being or computers [97].

4.6.1 Beginning of ISO 10303

The first step for STEP begins in 1979 through the development of Initial Graphics Exchange Specification (IGES) which was the first standard format for the CAD information exchange [100]. The only problem was the incapability of IGES to exchange data among free form surfaces [101]. Then, Verband Der Automobilindustri (VDA) developed their Verband der

Automobilindustri Flachenschnittelle (VDAFS) to focus on overcoming problem occurred in IGES [102].

On 1984, the initial development of ISO 10303 has begun to solve the problems of IGES and VDAFS which then proceeded to first significant publication of STEP, where single model of Integrated Product Information Model (IPIM) was assembled from large set of data models [103]. During 1985, STEP was redirected to utilise Application Protocol (AP) as a subset, and the architecture of AP continued to be developed in the following years. Until 1994, the first version of STEP finally was adopted as an ISO standard [98].

4.6.2 Development of STEP

During 1994, ISO has published initial release of STEP parts 1, 11, 21, 31, 42, 43, 44, 46, 101, AP201 and AP 203 [104]. Later during 2002, STEP introduced AP 202, AP 209, AP 210, AP 212, AP 214, AP 224, AP 225, AP 227 and AP 232 which improved the capabilities and expanded the industries to automotive, electronic manufacturing, aerospace and others [85].

The standard is grouped into different parts such as description method, application protocols, implementation methods and conformance tools. Each of this part is represented by numbers [105] as shown in Table 4.1.

Table 4.1 : STEP standard parts [105]

Part	Number	Description
Overview and fundamental principles	11-19	Gives STEP overview and explain its fundamental principles
Description methods	11-19	Covers EXPRESS and EXPRESS-G form
Implementation methods	21-29	Covers methods of EXPRESS modelled data representation
Conformance testing	31-39	Covers concept of conformance testing with actual test methods and requirements
Integrated generic resources	41-59	Covers EXPRESS models use for geometry, topology and tolerance
Integrated application resources	101-199	Covers specific subject domain EXPRESS models
Application protocols	201-299	Covers parts intended for implementation in industries

4.7 Case Studies

The G-code language is clearly insufficient for this. Even though existing CNC systems have become more and more sophisticated, incompatibility between their proprietary data restricts further productivity enhancement of CNC-based machining. Furthermore, since each system has its own data format, the same information must be entered multiple times into multiple systems leading to redundancy and possible errors [79]. There are few major problems in G-code shown in Figure 4.6 that leading up to the development of STEP which will explained further in the chapter. The problems are summarized from various journals and research that discussed the drawbacks of G-code in its nature.

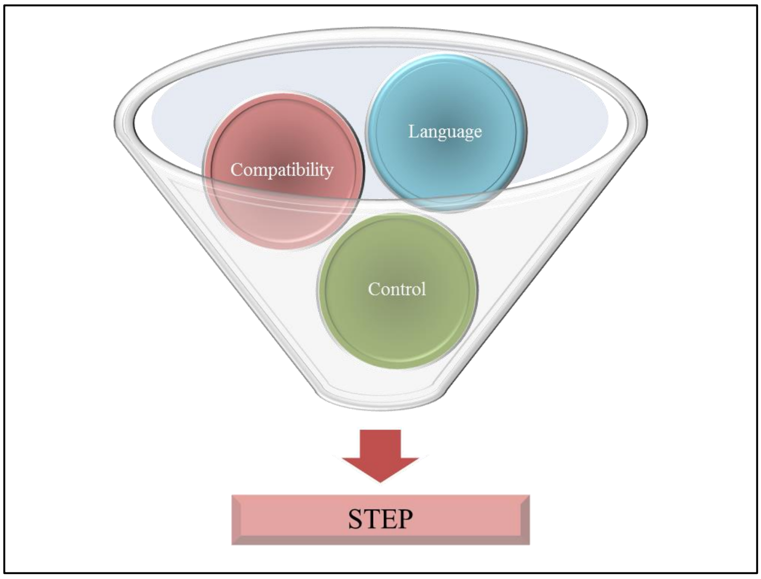

Figure 4.6 : G-code main problems leading to STEP

The main problems with G-code are summarized into three main components, which are; compatibility, language and control.

4.7.1 Compatibility

The information flow is uni-directional from design to manufacturing, which means there is no feedback for changes and modifications of machining problems on shop floor that could be done [88]. Furthermore, the CAD data is not directly used on the machine tool. In terms of low level data, it is processed by the means of machine specific post processor, which makes verification and simulations problematic due to incomplete data set.

This standard is not capable to process Spline data which has becoming a demand in the area of five axis milling or high speed machining [106]. It is almost impossible to run different CNC machines on a same NC program under this standard, and unfeasible to receive feedback from CNC to CAD/CAM [107] as shown in Figure 4.7 which indicates that the system only moves forward without any data feedback.

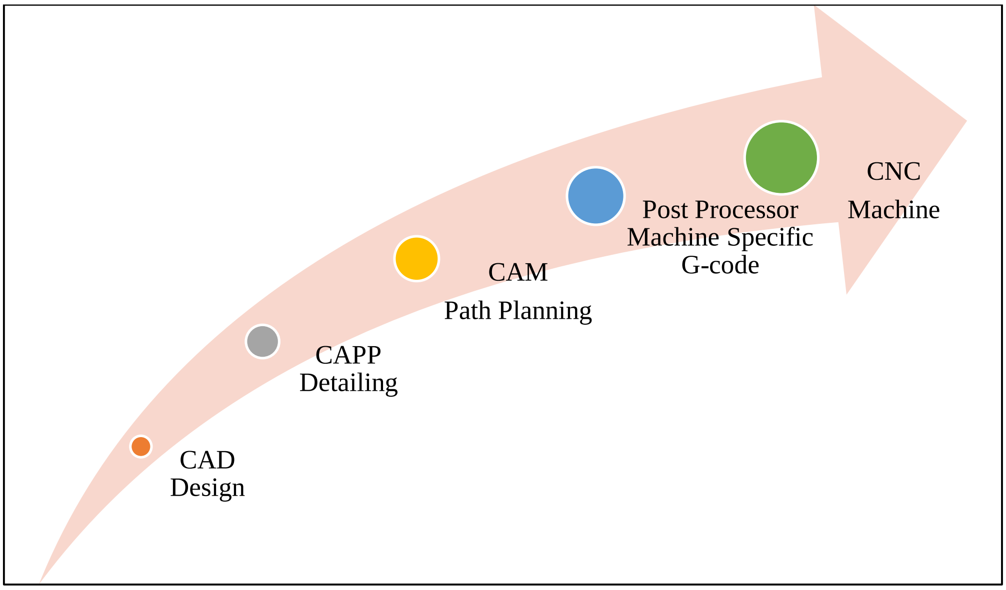

Figure 4.7 : Manufacturing system information flow

4.7.2 Language

Vendor usually enhances the language with further extension commands to provide new features, however these extensions are not covered by ISO 6983 [88]. Therefore, the programs are not exchangeable between other machine tools and becomes machine specific language [108] as shown in Figure 4.8.

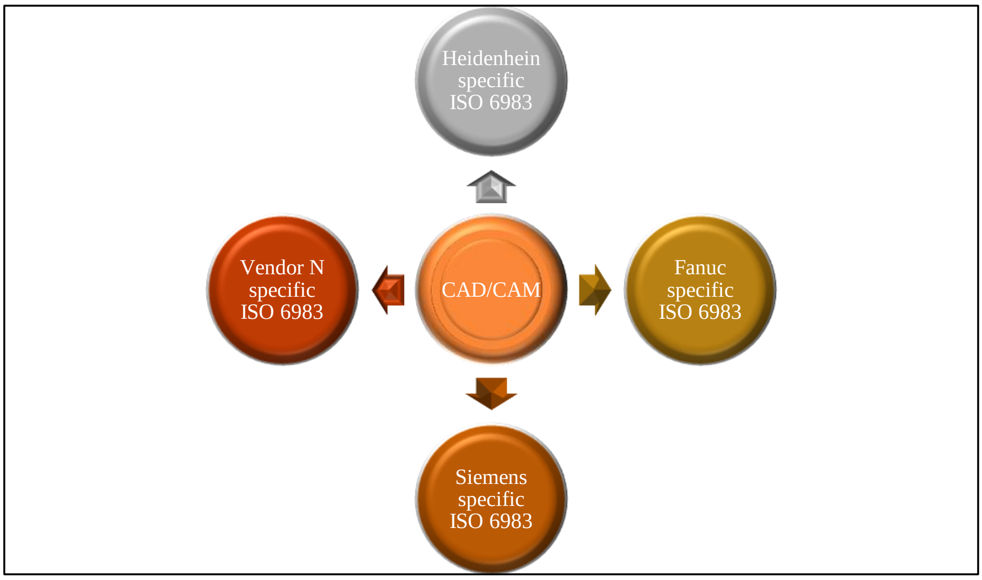

Figure 4.8 : Current vendor situation in CAD/CAM for ISO 6983

Furthermore, it takes a long NC programming for even a simple geometry with unintuitive code [107]. Due to lack of information in G-code, the reusability of the code itself is very poor and quite difficult to update or change the code on it is generated [110]. It is difficult to trace the loss data and information [109] from the code that is not compatible with higher level system [111] as shown on Figure 4.9.

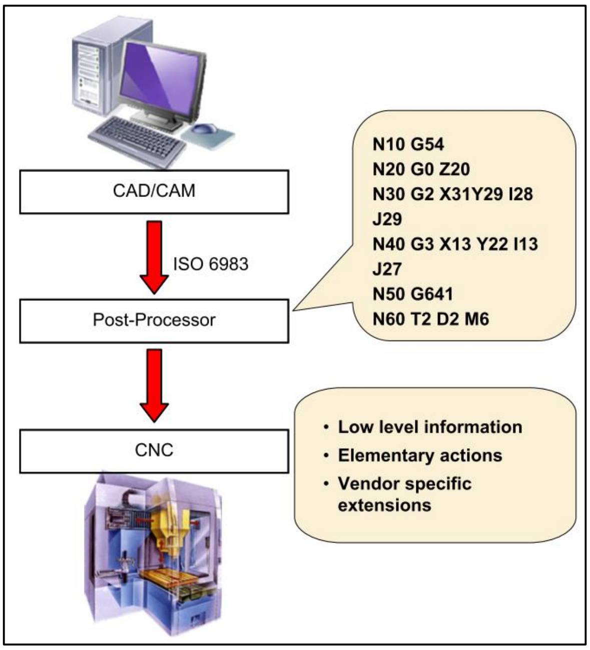

Figure 4.9 : G-code language programming flows [109]

4.7.3 Control

The ISO 6983 defines the syntax of program statements, but in most cases leaves the semantic unclear, together with a low level limited control over program execution [112]. When processed in a CAM system by machine specific post processor, these programs becomes machine dependent [92]. The standard's language is too focused on programming the path of the cutter centre location with respect to the machine axis, rather than the machining tasks with respect to the part [113].

Therefore, the control of the program execution at the machine is limited, causing difficulties to make changes in program workshop [88]. In addition, ISO 6983 also has poor support for kinematics features of 5 axis machine with the flaw of lacking enough information about the material, part and stock [107].

These problems (compatibility, language, control) has led to a need of new data interface, even though in reality G-code is still well accepted standard worldwide [107] and useful because they integrate the micro process plan with operator experience [114]. Therefore, this research still needs G-code as part of its system for a better working environment in CNC.

4.8 Framework

Figure 4.8 covers the research framework for the development of sustainable controller.

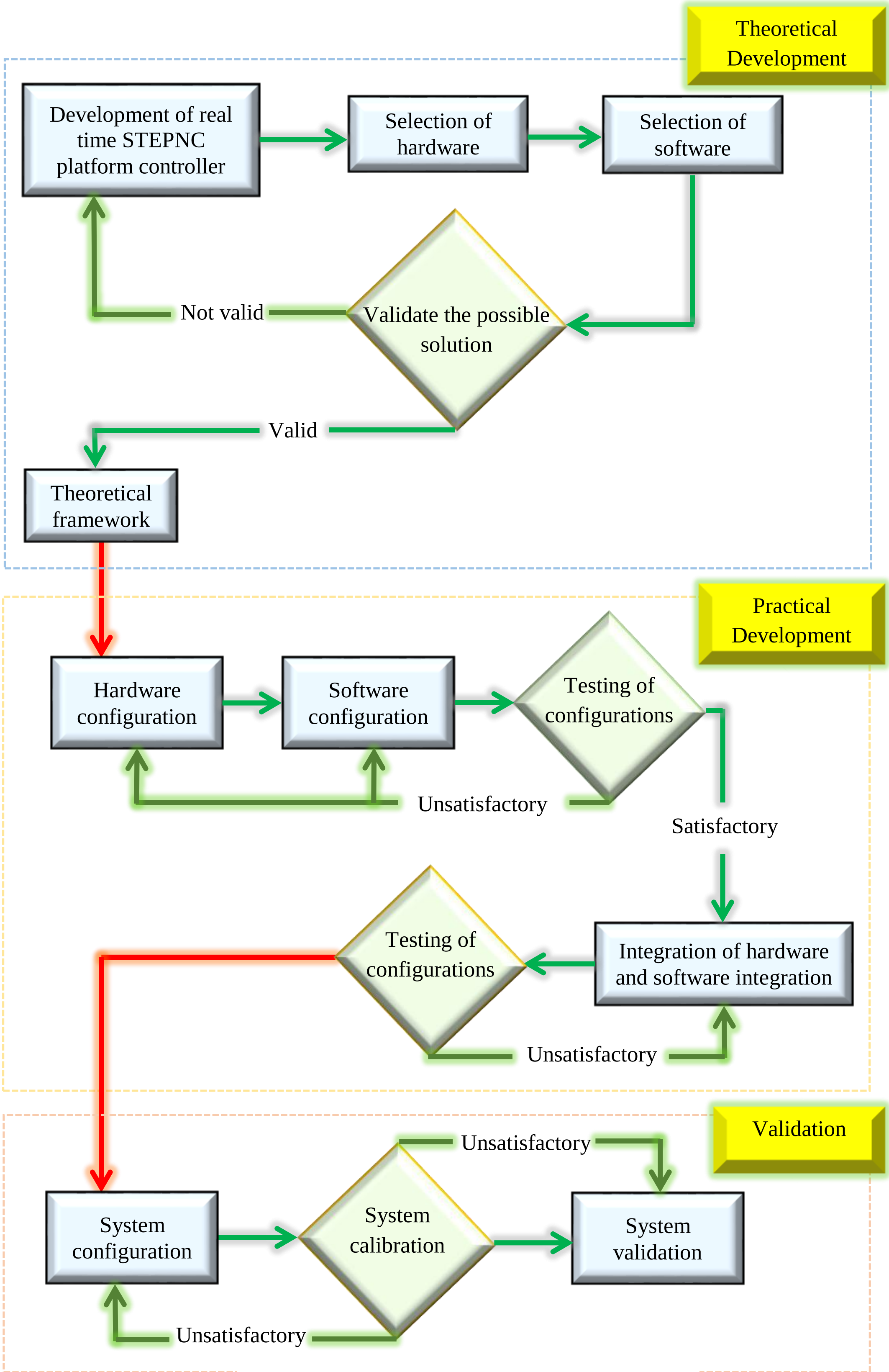

Figure 4.10 : Research framework

4.8.1 Hardware development

The developed STEP-NC controller from [115], has made CNC machine becomes independent from its built in controller. The CNC machine is now controlled from normal Personal Computer (PC) through serial port via Universal Motion Interface (UMI 7764). This controller is an upgrade from the previous technique by [116]. The hardware configuration will be divided into CNC Machine to PC system and PC to Android.

4.8.2 CNC Machine to PC

The specification for the CNC Machine (DENFORD NOVAMILL) is shown on Table 4.2 which is used to connect to the PC. It is a 3 axis CNC machine with 3 stepper motors and spindle. While

Table 4.3 shows the specifications for the PC and other components that connect the CNC machine to properly function.

Table 4.2: Denford Novamill Specification [115]

No.	Part	Description
1.	X- Axis	Stepper motor 200 steps/rev
2.	Y-Axis	Stepper motor 200 steps/rev
3.	Z-Axis	Stepper motor 200 steps/rev
4.	Spindle	0.5 HP
5.	Automatic Tool Changer (ATC)	Motor Drive Panasonic

Table 4.3: PC and connecting components specifications [115]

No.	Part	Description
1.	PC	Windows XP Intel Pentium
2.	Motion Control Card	PCI 7334
3.	Universal Motion Interface	UMI 7764
4.	I/O Card	PCI 6221
5.	Encoder	Rotary ENC-7742
6.	Compressor	PS 16bar

4.8.3 PC to Android

The Android programming framework is illustrated as in Figure 4.11.

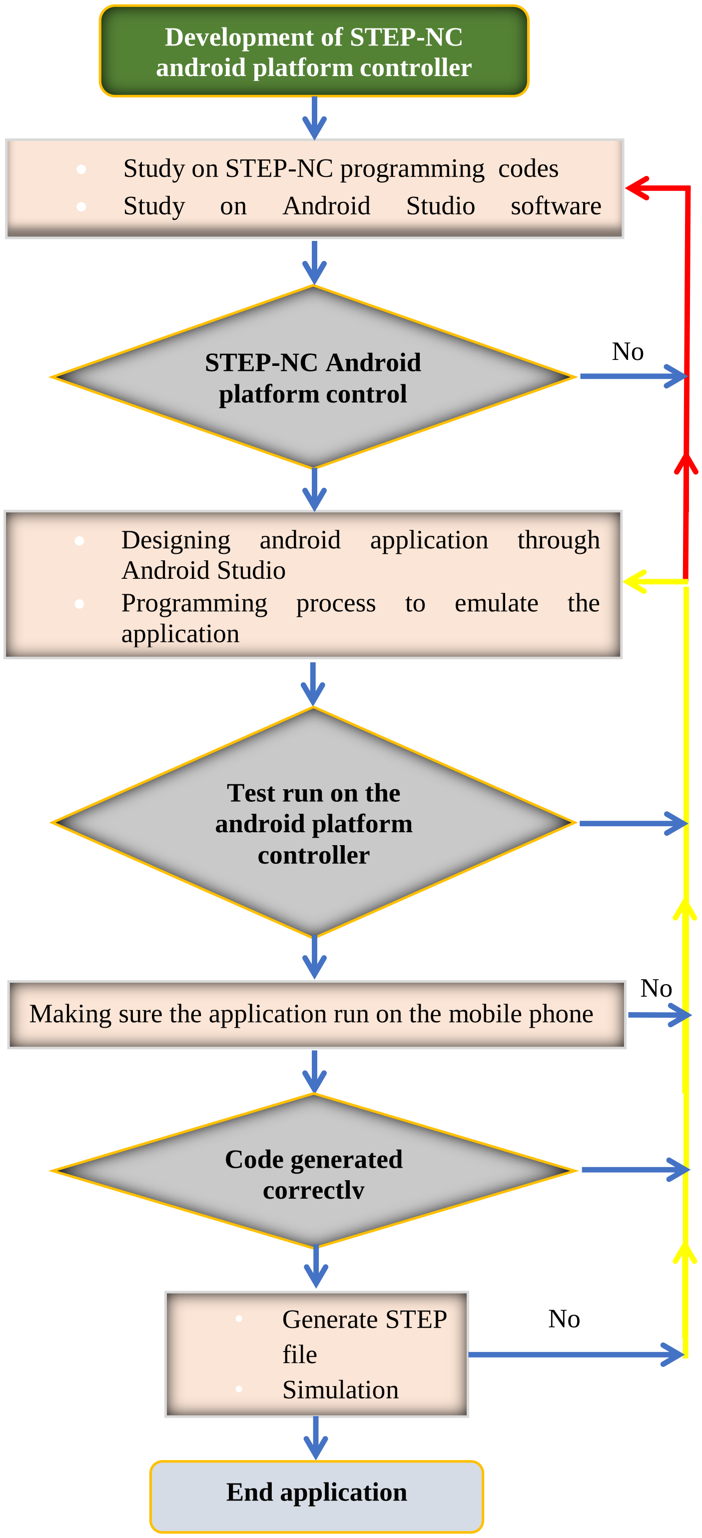

Figure 4.11 : Android platform development

The PC will then connect to android via wireless/Bluetooth system which will be installed in the system module in the UMI 7764. The UMI 7764 has already incorporated several components into the modules such as 3D simulation and interpreters, thus wireless/Bluetooth connection will be installed in order to connect the PC to android. Figure 4.12 shows the modules for the UMI 7764 that connects PC to CNC machine with addition of wireless/ Bluetooth modules.

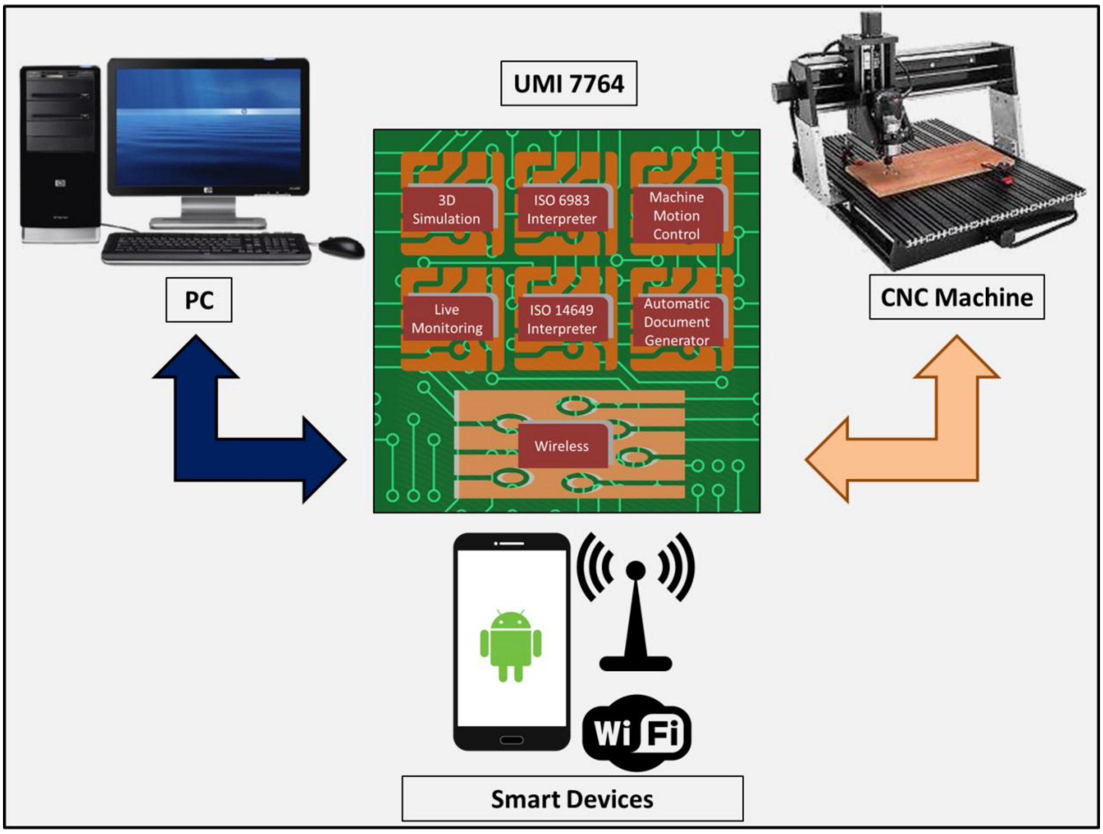

Figure 4.12 : UMI 7764 with additional wireless/ Bluetooth module

4.9 Software development

LabVIEW was used to program the STEP NC controller from the PC to the CNC machine because of its compatibility with National Instruments (NI) UMI 7764. This allows wireless/ Bluetooth modules being installed into the system to connect the android to the PC.

The android platform is programmed by using Android Studio software for better interface and smooth operation system.

4.10 Hardware and Software integration

Figure 4.13 shows the integration system between android, PC and CNC machine. It shows that the CNC machine could be controlled by PC through STEP NC software which ultimately controlled by android platform through wireless/ Bluetooth.

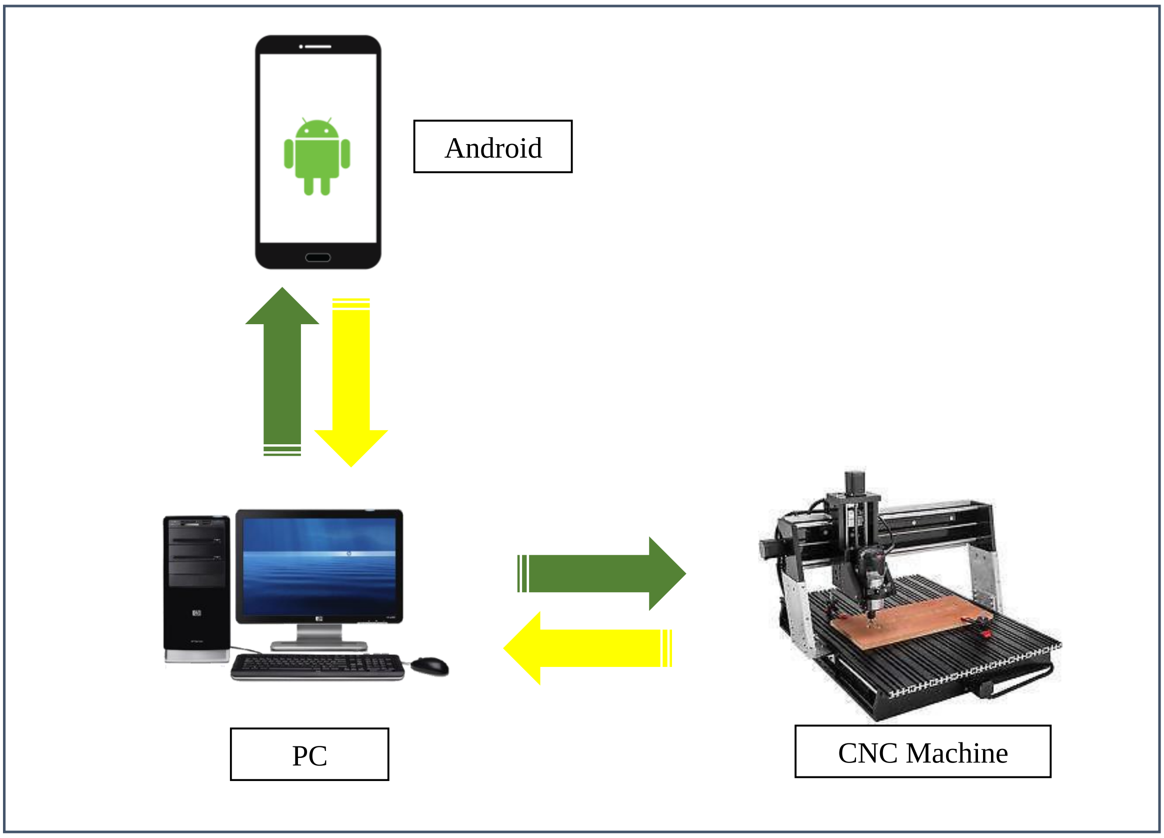

Figure 4.13: Integrated system

4.11 Data analytics and digital trust are the foundation of Industry 4.0

Data are lie at the heart of the Fourth Industrial Revolution, however It remains the massive growing flow of information on a wide range of value Limited without the presence of the appropriate structure and analysis techniques broader infrastructure support, must be the existence of networks related capabilities in order to achieve the full potential for large data. Data is originating from numerous sources, in various formats, and there is a need to consolidate internal data with data from outside sources. Expert and effective data analytics is essential to utilizing data to create value. Moreover, with such a significant number of purposes of entry, companies need to take a rigorous, proactive approach to data security and data property management, and work to build digital trust.

Figure 4.14 presents the general scheme of an importance of resources to create a system of closed-loop manufacturing process and inspection. The system is completely integrated with multi-functional of operating systems that adhering to connect the smartphone to CNC machine.

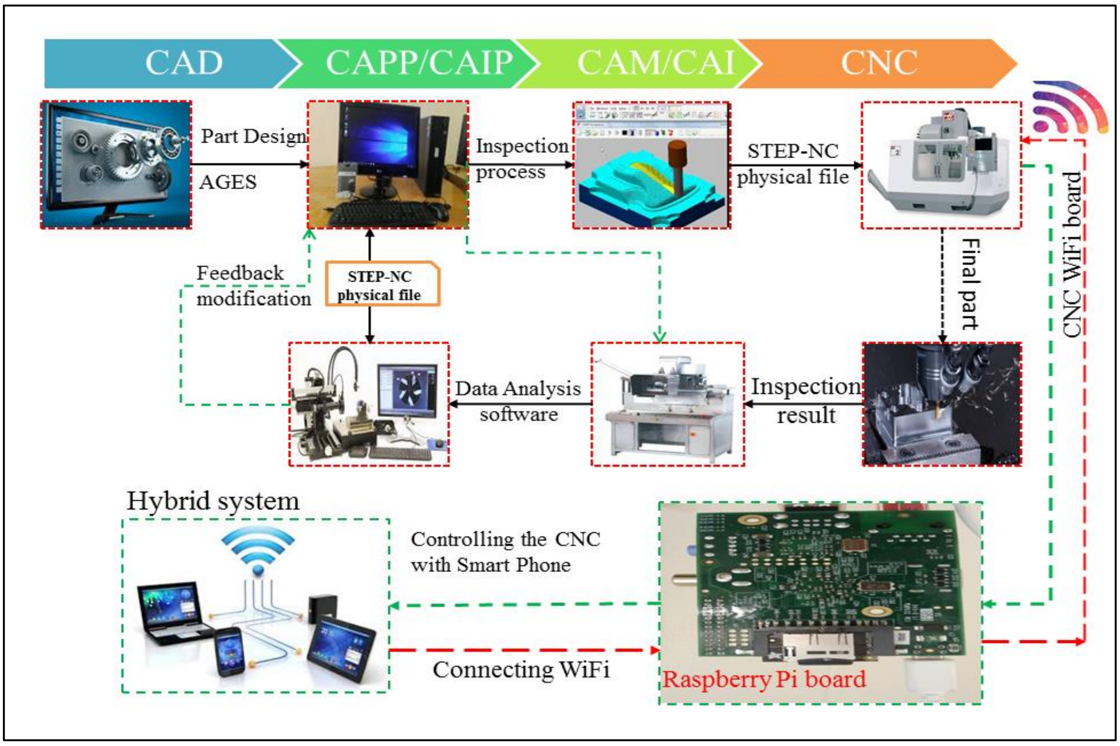

Figure 4.14 Framework of whole system integration of closed-loop with hybrid system.

The model illustrates the degree of complexity of these activities, and the solution approach development. In contrast, the closed-loop system is considered to be a manufacture bi-directional communication which maintains with each of the processes involved within the context of industry. Proper handling of perm will improve production, promote continuous improvement at all levels and save time on production issues. The design of architecture with information structure provides the means necessary for development of future methods of solutions.

CHAPTER 5

CONCLUSIONS

5.1 Contribution towards IR 4.0

The technology of CNC machines has contributed a lot to the manufacturing world. However ISO 6893 which serves as the early generation of machining language has limited the machine information and transference of data, which is not aligned with IR 4.0. Thus, this situation had brought about the development of the new programming language, which is ISO 10303 in order to replace the ISO 6893.

Further developments created variety of Application Protocol and STEP NC data which in evidently brings the CNC technology to a higher level. Therefore, with the advancement of hardware and software technology, the CNC machines now are able to be connected online and operated from anywhere around the world. Through the introduction of virtual component based technique for CNC machine control, enabling the machine to directly read the interpreted STEP file without needing to convert to G Code.

The shop floor data modifications facilities between the interpreter and CNC machine motion control has enable editing for both ISO data interfaces between STEP and G Code. Furthermore, with the advancement of web cameras, the CNC machining process can be monitored via online which makes it easier to detect and problems during productions.

5.2 Conclusions

This publication generally highlights the advancement of IR 4.0 and its effect on CNC's world. Generally, the developments of these kinds of systems are high in cost. However, the need and benefit the will be reaped are worth every penny. The commercial CNC systems, based on IR 4.0 using personal computers as it platform, provides wide options for the use of third party hardware and software.

This development can plan an important role in the growth of small industries and shop floor CNC users. These systems can also be used to convert old CNC or manual operated machines into modern CNC units. The development of these kids of system was mostly highlighted by various countries such as USE, UK, Germany, Japan, China, New Zealand and Switzerland based on various approaches. Thus, it is imperative for Malaysia to also follow these steps to reach our vision of becoming a nation equipped with IR 4.0 technology. Overall, the combination of virtual component technology from both software and hardware with STEP has highlighted numerous field of research which led to the opening new doors for further improvement and contributions for preparing Malaysia towards IR 4.0.

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