THE IMPACT OF LEAN PRODUCTION ON THE SUSTAINABLE ORGANISATIONAL PERFORMANCE: THE MODERATING ROLE OF INDUSTRY 4.0 TECHNOLOGIES ADOPTION

OOI LYN LIQ

UNIVERSITI SAINS MALAYSIA

2022

THE IMPACT OF LEAN PRODUCTION ON THE SUSTAINABLE ORGANISATIONAL PERFORMANCE: THE MODERATING ROLE OF INDUSTRY 4.0 TECHNOLOGIES ADOPTION

by

OOI LYN LIQ

Thesis submitted in fulfilment of the requirements
for the degree of
Master of Arts

April 2022

ACKNOWLEDGEMENT

This thesis marks the end of my journey in obtaining my master study. At the end of my thesis, it is a pleasant task to convey my gratitude to all those who helped in many ways to the accomplishment of this study and made it an unforgettable experience for me. First and foremost, my deepest appreciation, gratitude and heartfelt thanks go to my main supervisors, Associate Professor Dr. Teh Sin Yin and Dr. Sharon Cheang Peck Yeng. I have received a great deal of patience, guidance, support, and encouragement from them throughout this challenging journey. I could not have asked for better supervisors like them for my master study. In addition, many thanks to Universiti Sains Malaysia (USM) for awarding me the Graduate Student Financial Assistance (Gra-ASSIST). Receiving this scholarship supported me in reducing my financial burdens. Moreover, I would like to extend my sincere thanks and appreciation to the academicians and industry practitioners by providing their insightful comments and feedbacks to improve my survey instruments. My profound gratitude also goes to all the respondents on their valuable time in completing the questionnaires. Last but not least, I would like to thank my parent for their unconditional support, love, and understanding. Without whom I could not have made it here. Thank you.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

3Q	Third Quarter
4IR	Fourth Industry Revolution
4Q	Fourth Quarter
AVE	Average Variance Extracted
BNM	Bank Negara Malaysia
CMV	Common Method Variance
COVID-19	Coronavirus Disease 2019
CPS	Cyber Physical Systems
CR	Composite Reliability
DDI	Domestic Direct Investments
DoSM	Department of Statistics Malaysia
E-mail	Electronic Mail
EPU	Economic Planning Unit
f^2	Effect Size to R^2
FDI	Foreign Direct Investments
FMM	Federation of Malaysian Manufacturers
GDP	Gross Domestic Product
HRM	Human Resources Management
HTMT	Heterotrait-Monotrait
ICT	Information and Communication Technology
Industry*4WRD*-RA	Industry*4WRD* Readiness Assessment
IT	Information Technology
JIT	Just-In-Time
LP	Lean Production

MCO	Movement Control Order
MDEC	Malaysia Digital Economy Corporation
MIDA	Malaysia Investment Development Authority
MITI	Malaysia of International Trade and Ministry
MNC	Multinational Corporation
MPC	Malaysia Productivity Corporation
PLS	Partial Least Squares
β	Path Coefficient
Q^2	Predictive Relevance
q^2	The q^2 Effect Size
R^2	Coefficient of Determination
R&D	Research and Development
SDGs	Sustainable Development Goals
SEA	Southeast Asia
SEM	Structural Equation Modelling
SMEs	Small Medium Enterprises
SOP	Sustainable Organisational Performance
SPC	Statistical Process Control
SPSS	Statistical Packages for the Social Sciences
STR	Setup Time Reduction
TPM	Total Productive Maintenance
TPS	Toyota Production System
TQM	Total Quality Control
WCED	United Nations World Commission on Environment and Development
WEF	World Economic Forum

LIST OF APPENDICES

KESAN PENGELUARAN LEAN TERHADAP PRESTASI ORGANISASI LESTARI: PERANAN ADOPSI TEKNOLOGI INDUSTRI 4.0 SEBAGAI MODERATOR

ABSTRAK

Banyak syarikat pembuatan yang masih bergelut untuk mengguna pakai aktiviti teknologi tinggi Industri 4.0 dalam operasi di Malaysia. Cabarannya termasuk mengimbang antara memacu pertumbuhan ekonomi, kualiti hidup manusia yang tinggi, dan pemuliharaan alam sekitar dalam industri pembuatan. Tambahanya, satu set 10 Pengeluaran *Lean* (LP) yang mewakili proses hujung ke hujung syarikat pembuatan belum dikaji secara menyeluruh mengenai prestasi organisasi lestari (SOP). Objektif kajian ini adalah untuk mengkaji peranan Adopsi Teknologi Industri 4.0 dalam hubungan antara LP dan SOP dalam industri pembuatan. Kajian ini mencadangkan rangka kerja penyelidikan tentang hubungan langsung antara pengeluaran Lean dengan prestasi organisasi lestari berdasarkan kajian literatur berkaitan, *Lean Production Theory*, dan *Triple Bottom Line Theory*, dengan Adopsi Teknologi Industri 4.0 sebagai moderator. Kaedah tinjauan kuantitatif digunakan dalam kajian ini untuk proses pengumpulan data. Pihak pengurusan pertengahan atau atasan, seperti pengarah, pengurus, penyelia atau penyelaras dalam syarikat pembuatan merupakan responden yang disasarkan dalam kajian ini. Sebanyak 1000 set soal selidik telah dihantar melalui e-mel kepada syarikat pembuatan yang tersenarai dalam Persatuan Pengilang-Pengilang Malaysia Direktori Industri Malaysia 2020 (Edisi ke-51) dan kadar respons sebanyak 25.3% telah diterima. Dapatan kajian ini mampu menyokong objektif kajian. Statistik deskriptif dikira menggunakan IBM Pakej Statistik untuk Sains Sosial *(IBM SPSS)* untuk mengkaji faktor demografi responden. Pemodelan Persamaan Struktur Kuasa Dua Separa Terkecil *(PLS-SEM)* digunakan untuk penilaian ukuran dan model struktur. Dapatan kajian ini menyokong objektif kajian. Hasil kajian ini mendapati bahawa kesan penyederhanaan Adopsi Teknologi Industri 4.0 menyederhana secara positif dalam hubungan langsung 5 dimensi pengeluaran *Lean* ke arah prestasi organisasi lestari, iaitu Maklum Balas Pembekal, Pembangunan Pembekal, Aliran Berterusan, Pengurangan Masa Persediaan, dan Penyelenggaraan Produktif Jumlah. Sebaliknya, kesan penyederhanaan Adopsi Teknologi Industri 4.0 dengan Penghantaran Tepat Pada Masa, Penglibatan Pelanggan, Sistem Tarik, Kawalan Proses Statistik, dan Penglibatan Pekerja didapati tidak berkait secara signifikan dengan prestasi organisasi lestari. Implikasi teori dan praktikal telah dikemukakan berdasarkan dapatan kajian ini. Tesis ini diakhiri dengan perbincangan tentang batasan kajian dan cadangan untuk penyelidikan masa depan.

THE IMPACT OF LEAN PRODUCTION ON THE SUSTAINABLE ORGANISATIONAL PERFORMANCE: THE MODERATING ROLE OF INDUSTRY 4.0 TECHNOLOGIES ADOPTION

ABSTRACT

In Malaysia, many manufacturing companies are still struggling to adopt Industry 4.0 high-tech activities into operations. There is a challenge to balance between driving economic growth, high quality of living, and environmental conservation in manufacturing industry. In addition, a set of 10 Lean Production (LP) that represents manufacturing companies' end-to-end processes has not been investigated holistically on Sustainable Organisational Performance (SOP). The objective of this study is to examine the moderating role of Industry 4.0 Technologies Adoption in the relationship between LP and SOP in manufacturing industry. This study proposed a research framework on the direct relationship between LP and SOP based on related literature review, Lean Production Theory, and Triple Bottom Line Theory, with Industry 4.0 Technologies Adoption as a moderator. A quantitative survey method is utilized in this study for data collection process. The middle or top management, such as director, manager, supervisor or coordinator in the manufacturing companies are the targeted respondents in this study. A total of 1000 sets of questionnaires were e-mailed to manufacturing companies listed in the Federation of Malaysian Manufacturers (FMM) Directory of Malaysia Industries 2020 (51st Edition) and a response rate of 25.3% were received. The findings of this study can support the research objective. The descriptive statistics were calculated using Statistical Package for The Social Sciences (SPSS) to study the demographic factors of respondents. The Partial Least Square Structural Equation Modelling (PLS-SEM) is applied for the assessments of measurement and structural model. The findings of this study are able to support the research objective. This study revealed that Industry 4.0 Technologies Adoption positively moderated the direct relationships of 5 LP dimensions toward SOP, namely Supplier Feedback, Supplier Development, Continuous Flow, Setup Time Reduction, and Total Productive Maintenance. In contrast, the moderating effect of Industry 4.0 Technologies Adoption links with Just-In-Time Delivery, Customer Involvement, Pull System, Statistical Process Control, and Employee Involvement were found not significantly related to SOP. The theoretical and practical implications were presented based on the findings of this study. This study concluded with a discussion of limitations and recommendations for future research.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia is a Southeast Asia (SEA) nation that shares borders with Thailand, Singapore, and Indonesia. Malaysia is one of Asia's best-performing countries with annual gross domestic product (GDP) growth of 5.3% since 2010 (Asia Perspective, 2020). In the 1970s, Malaysia started to follow in the footsteps of the Four Asian Tiger economics, notably South Korea, Taiwan, Hong Kong, and Singapore, by shifting from mining and agriculture towards a manufacturing-based economy. However, rapid industrialisation growth has also been significantly increased the amount of solid waste generated in the nation, which negatively impacts the environment. To maintain competitiveness sustainably, manufacturing industry in Malaysia is being urged to shift to higher value-added processes, digitalisation, advanced manufacturing technologies, and sustainable resources utilisation. A modern Fourth Industrial Revolution (4IR) paradigm shift is driven by technological advancements that represent an evolution of the traditional Lean Production (LP) system. Manufacturers will obtain some valuable lean 4IR insights into accomplishing a significant level of sustainable performance by complementing LP and Industry 4.0 Technologies.

Section 1.2 discusses the background of study, followed by Section 1.3 describes manufacturing industry in Malaysia. Next, problem statement listed in Section 1.4. Subsequently, Section 1.5 identifies research objective, followed by research question presented in Section 1.6. For Section 1.7, significance of the study is discussed. Definitions of key terms are explained in Section 1.8. Lastly, Section 1.9 outlines organisation of the remaining chapters.

1.2 Background of the Study

Toyota Motor Corporation was the first to invent the Toyota Production System (TPS) during 1950s (Black, 2007). The basic idea of TPS is to eliminate waste, or so-called *Muda* in Japanese. Waste refers to any waste activities incurred in the manufacturing and production process (Ohno, 1988). Defects, overproduction, waiting, under-utilisation of talent, transportation, inventory, motion, and extra-processing are the 8 types of wastes that should be avoided (Klein LL et al., 2021). The term "Lean Production" was first introduced by Krafcik in 1988 and subsequently appeared in the popular book "Lean Thinking – Banish Waste and Create Wealth in Your Corporation" by Womack and Jones (1997). LP is now widely accepted and implemented in various industrial environments across countries (Chiarini et al., 2018). Since then, TPS has been more commonly rephrased as "Lean Manufacturing".

The lean consists of 5 main principles (Alefari et al., 2020) as presented in Figure 1.1. The first principle is identifying value from the perspective of the customer, the second principle is drawing the value stream for each product or product family, the third principle is generating flow without any interruptions or bottlenecks, the fourth principle is employing a pull system that starts from the customer, and lastly, the fifth principle is practicing perfection by continuously eliminating unwanted elements. These principles can be applied to any business (Haque & James-Moore, 2004). LP is a system that seeks to minimise production costs while maximise profits by eliminating non-value-added activities from the customer's viewpoint (Johan et al., 2019). Once non-added value activities increase, the profit margin will be decreased subsequently. Customers are unwilling to pay for any non-value-added activities. Therefore, LP is critical for removing waste activities or processes that absorb resources but produce no value.

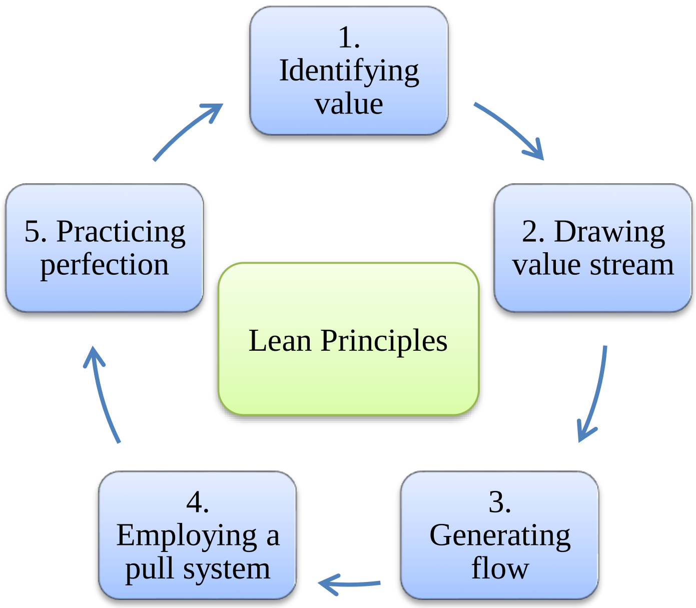


Figure 1.1 The 5 main lean principles

There are 10 dimensions of LP identified by Shah and Ward in 2007. The 10 dimensions of LP are namely: Supplier Feedback, Just-In-Time (JIT) Delivery, Supplier Development, Customer Involvement, Pull System, Continuous Flow, Setup Time Reduction (STR), Statistical Process Control (SPC), Total Productive Maintenance (TPM), and Employee Involvement. The 10 dimensions of LP represent a manufacturing company's end-to-end processes from upstream suppliers to downstream customers.

Nevertheless, in the era of Industry 4.0, manufacturers all over the world have recognised that LP in manufacturing processes is no longer sufficient to address competitive operating pressure (Miqueo et al., 2020; Rosin et al., 2020). Most of the lean manufacturing companies recognised that business sustainability can be reinforced through innovation in technologies, processes, products or services, and business models (Hubbard, 2009; Kamble et al., 2020).

In addition, the manufacturing industry is under pressure by various stakeholders to manage industry operations responsibly in a sustainable manner (Mousa & Othman, 2020). From the report conveyed by World Economic Forum (WEF) in 2020, 74% of employees require their chief executive officers to clarify the efforts that they have done to benefit the society and environment. This has propelled the manufacturing industry to distinguish new approaches integrate with LP in achieving sustainable performance towards society and environment.

From the global perspective, there are more than 80% of global businesses planning to speed up the digital transformation in their operations and wishing to accelerate the automation in production system rapidly (WEF, 2020). Most of the companies have adjusted to remote work and increased their investments in advanced technologies. Notably, chief executive officers and chief operating officers believe that remote presence production system would be a long-term and advantageous success (WEF, 2020). In other words, businesses that are more accessible to Industry 4.0 Technologies are more likely to accelerate their recovery from the Coronavirus Disease 2019 (COVID-19) implications (WEF, 2020).

Malaysia Productivity Corporation (MPC) has introduced the Lean Roadmap to encourage lean management in 2014. Lean management is a management philosophy that reduces the time between customer orders and products or services delivered through wastes elimination (Ohno, 1988). Lean management complements existing quality and productivity, putting all efforts to increase process efficiency and enhance national competitiveness at the global level. The MPC's Lean Roadmap is divided into 6 phases as presented in Figure 1.2. According to MPC, the foundation of Lean Roadmap is lean thinking. Lean thinking can be applied as an organisational culture in the pursuit of organisational excellence.

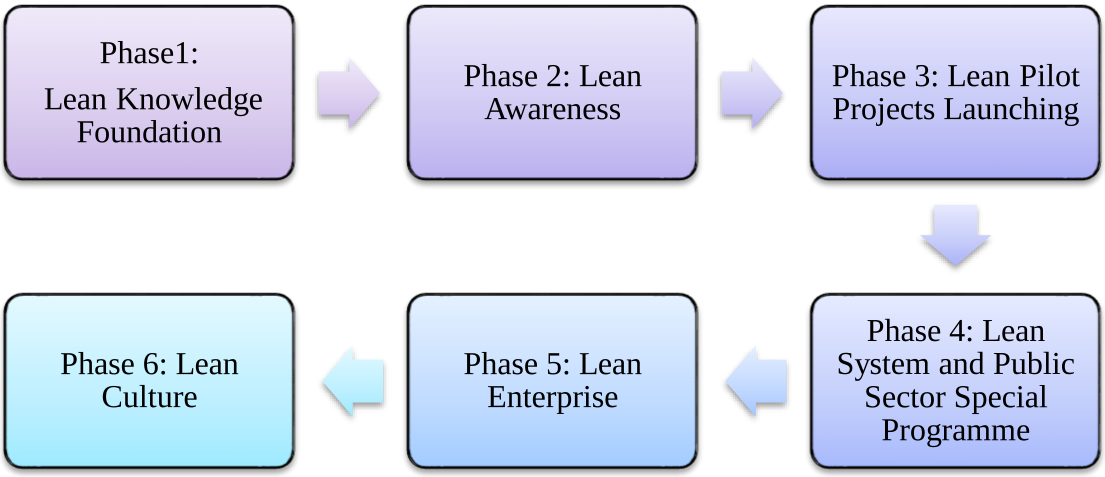


Figure 1.2 The 6 phases of MPC's lean roadmap

Manufacturing companies are keen to improve their manufacturing system in sustaining competitiveness. Manufacturing companies must be capable to meet customer expectations and demand fluctuations by offering superior quality products and services (Rasi et al., 2015). Furthermore, in year 2020, the outbreak of new viral pneumonia, COVID-19 has affected the global economy including Malaysia. The government of Malaysia had enforced Movement Control Order (MCO) since March 18, 2020 to break the COVID-19 transmission chain. Bank Negara Malaysia (BNM) reported that the COVID-19 pandemic had driven 5.6% contraction of Malaysia's economy in 2020. The COVID-19 outbreak during 2020 has been a challenging time for many Malaysians and manufacturing companies. Based on the results of semi-annual Business Conditions Survey in 2020 provided by Federation of Malaysian Manufacturers (FMM), the unexpected threat of COVID-19 outbreak had forced over half of the manufacturers to implement lean manufacturing promptly.

In Malaysia, restoring industrial activities without initiating environmental degradation is one of the challenging issues to solve. According to the summary of environment statistics conveyed by the Department of Statistics Malaysia (DoSM), there are 4.0 million tonnes of scheduled wastes produced in 2019. The power plant, metal refineries, chemical industries, and electrical and electronics industries contributed 57.1% to the total scheduled wastes, recorded as 2.3 million tonnes (DoSM, 2020).

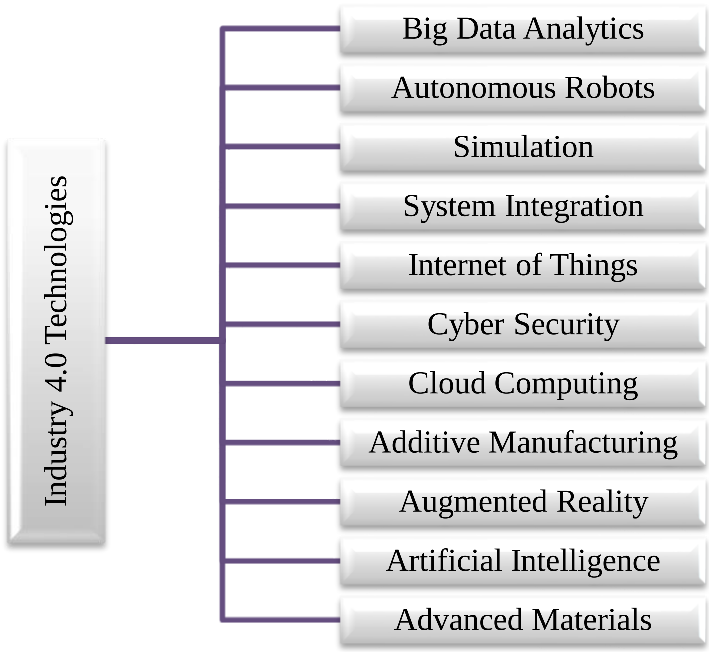
The MCO implemented since March 2020 provided relief to the environment by reducing industrial activities. Unfortunately, certain lawbreakers illegally disposed of industrial wastes into rivers. Year 2020, will be recognised as the year of frequent water disturbances, which impacted million households and businesses in Klang Valley. To that end, the government is evaluating the compounds and penalties imposed under the Environmental Quality Act 1974 by taking strict actions against industrial polluters (Prime Minister's Office, 2021).

Based on Voluntary National Review provided by Economic Planning Unit (EPU) in 2021, Malaysia aims to ensure the United Nation's Sustainable Development Goals (SDGs) are achieved in 2030 through poverty eradication, people's well-being improvement, and environmental protection. One of the drivers of the country's sustainability development has been recognised as Environmental Technology, which also known as Green Technology. Malaysia government will continue the Green Technology Financing Scheme 3.0 until 2022, with a fund allocation of RM2 billion to facilitate public and private institutions in achieving the SDGs (Prime Minister's Office, 2021). This is a great opportunity for Malaysian companies to invest in green technology and become environmentally sustainable.

In response to the Industry 4.0 paradigm, the Ministry of International Trade and Industry (MITI) has launched “Industry*4WRD*: National Policy on Industry 4.0” on October 31, 2018. The primary objective is to accelerate the transformation of digitalisation in the manufacturing sector and its related services (MITI, 2018). The Industry*4WRD* Readiness Assessment (Industry*4WRD*-RA) had been prepared by MITI to evaluate manufacturing companies’ current state of capabilities and readiness in Industry 4.0 Technologies adoption (MITI, 2019). The Industry*4WRD*-RA was implemented in line with the government’s goal to transform Malaysia into one of the top destinations for high-tech industries by 2025. Strong government support and successful cooperation among key public-private parties are essential in realising the technology-based transformation agenda. Malaysia Digital Economy Corporation (MDEC) and MPC are the agencies that collaborate with MITI.

In addition, the effort of moving manufacturing sector towards Industry 4.0 is complemented by the Malaysia Digital Economy Blueprint – MyDigital (2021 - 2030), which is outlined by Malaysian Investment Development Authority (MIDA), EPU, and MITI (MIDA, 2020a). The MyDigital blueprint has built the foundation to drive digitalisation across the nation by using advanced digital technologies and high-speed internet access (MIDA, 2020a). MyDigital blueprint facilitates in accelerating Industry 4.0 Technologies adoption and labor productivity improvement in the manufacturing sector. In the future, Malaysia able to become a regional leader in the digital economy and achieve sustainable socioeconomic development through MyDigital blueprint.

There are 9 pillars of technological advancements under Industry 4.0, namely Big Data Analytics, Autonomous Robots, Simulation, System Integration, Internet of Things, Cyber Security, Cloud Computing, Additive Manufacturing, and Augmented Reality (Bai et al., 2020; Liu et al., 2020; Rüßmann, et. al., 2015). These pillars describe the advanced technologies that can improve all aspects of manufacturing processes. In addition, MITI has presented two other pillars of emerging technologies, namely artificial intelligence and advanced materials, along with the nine pillars of Industry 4.0 Technologies in the "Industry*4WRD*: National Policy on Industry 4.0" (MITI, 2018). The introduction of the 11 pillars of Industry 4.0 Technologies is aimed at producing higher value-added, complicated, and complex products (MITI, 2018). The 11 pillars of Industry 4.0 Technologies are disclosed in Figure 1.3 and used in this study.



Sources: Rüßmann, et. al. (2015); MITI (2018); Bai et al. (2020); Liu et al. (2020)

Figure 1.3 The 11 pillars of Industry 4.0 Technologies

The introduction of Industry 4.0 Technologies and the adoption of its underlying technologies have heightened attention to the possibility of reaching the next level of operational excellence (Tortorella et al., 2021). To satisfy various stakeholders' requirements and remain competitive in the global market, manufacturing companies are under pressure to improve flexibility in both manufacturing system and business in an environmental-friendly manner (Lasi et al, 2014; Kamble et al., 2020). Therefore, manufacturing companies must constantly pursue new approaches. LP may achieve sustainable performance by using suitable advanced technologies.

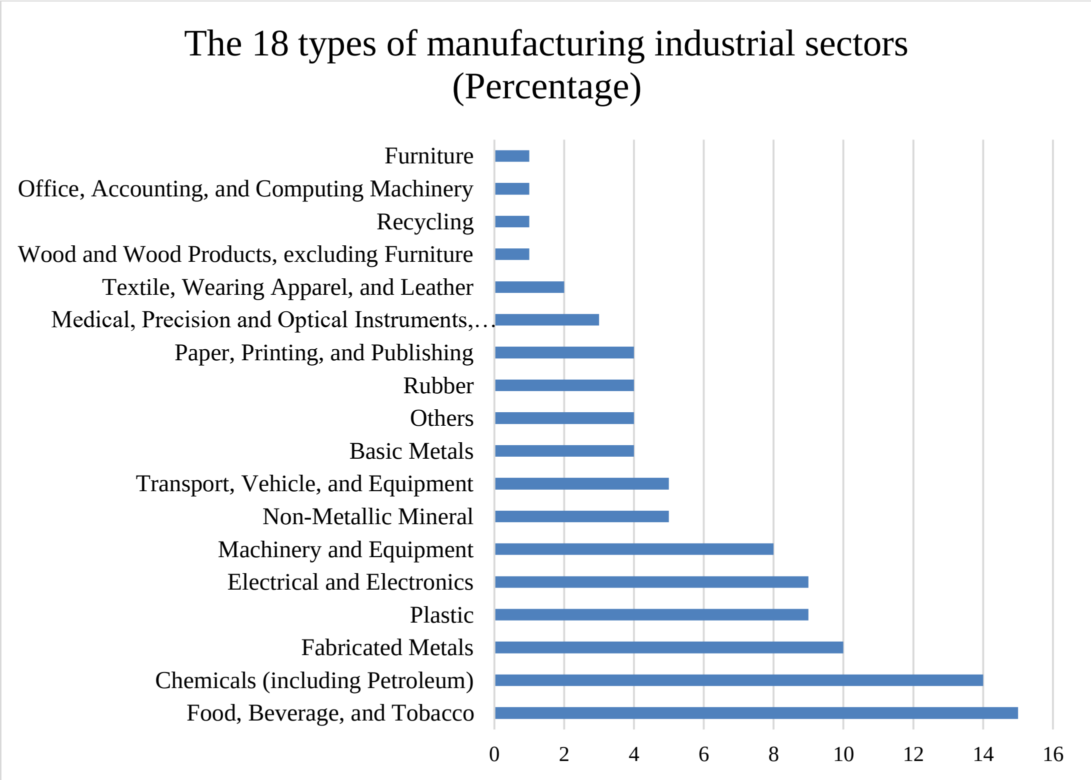
1.3 Manufacturing Industry in Malaysia

Manufacturing industry is a core industry to produce high-value and high-technology products under the 11th Malaysia Plan (Prime Minister's Office, 2015). In the 12th Malaysia Plan announced in 2021, the government emphasised on leveraging the benefits of digital technologies and improving productivity-boosting processes in the manufacturing sector to align with the "Industry*4WRD*: National Policy on Industry 4.0" (EPU, 2021b). The manufacturing sector was predicted to achieve an average growth of 5.7% per year (EPU, 2021b). The manufacturing industry in Malaysia has evolved dramatically as a result of transforming Malaysia's economy from an agricultural and mining to an industrial economy (Choy, 2004). As of December 2020, the total employees engaged in the manufacturing sector recorded 2, 199, 195 persons (DoSM, 2021b). Manufacturing sector has a large influence on the nation's prosperity, economy, and growth.

Selangor State is the most essential manufacturing hub that contributed to Malaysia's GDP, with 41.2% in year 2018 followed by economic corridor of Northern Cost Economic Region (16.3%) (Asia Perspective, 2020). The manufacturing hub in Selangor is dominated by electronics and optical products. Selangor State benefits from its proximity to the federal territories, two international airports, and the largest container port, Port Klang (Asia Perspective, 2020). For economic corridor of Northern Cost Economic Region, the largest manufacturing sub-sector is electronics, which accounting for more than 50% of all production outputs with infrastructure support at the cutting edge. The manufacturing sector in economic corridor of Northern

Cost Economic Region contributing around 30% of the region's GDP (Asia Perspective, 2020).

Based on the manufacturing companies lists obtained from FMM Directory of Malaysia Industries (2020), there are total 2840 manufacturing companies from 18 industrial sectors registered under FMM. The food, beverage, and tobacco industry accounts for the largest percent, reporting 15%, followed by chemicals and petrochemicals (14%), and fabricated metals (10%). The 18 types of manufacturing industrial sectors registered under FMM are presented in Figure 1.4.

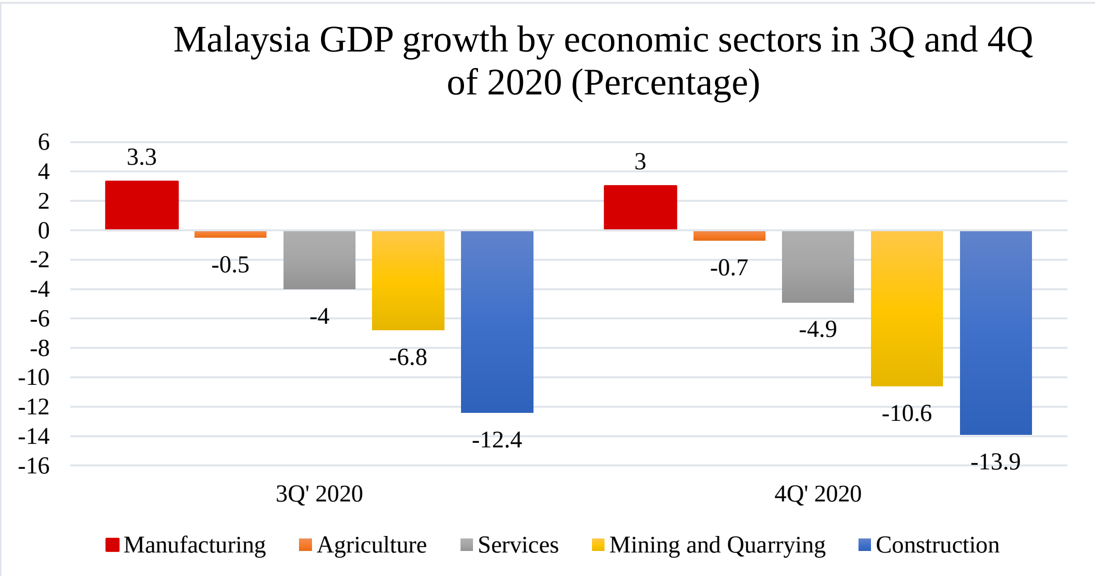


Source: FMM (2020)

Figure 1.4 The 18 types of industrial sectors under manufacturing industry

The priority industrial sectors within manufacturing industry in Malaysia that contribute to GDP are Electrical and Electronics, Machinery and Equipment, and Chemical and Petrochemical products (FMM, 2020; MITI, 2019). Malaysia government is focusing on these 3 sectors to re-energise the manufacturing sector (FMM, 2020). The leading sub-sector, Electrical and Electronics industry, has an outstanding contribution to nation's GDP growth, international trade, employment, and investments (MIDA, 2020c). Several sub-sectors also be valued by government, such as aerospace, automotive, medical devices, rubber, palm-oil, textiles, pharmaceuticals, and others that have shown the capabilities to deliver products in high value driven by research and development (R&D), sustainable manufacturing practices, and commitment to global standards (FMM, 2020; MITI, 2019).

In 2020, manufacturing sector contributes meaningfully to Malaysia's GDP as shown in Figure 1.5. The positive growth is driven by Petroleum, Chemical, Rubber, and Plastics products, followed by Electrical, Electronics, and Optical products (BNM, 2021; DoSM, 2021a). However, Malaysia's overall GDP recorded negative growth at 2.6% in the third quarter (3Q) and 3.4% in the fourth quarter (4Q) of 2020 due to the COVID-19 outbreak. The reduction owning to declines in all economic sectors except manufacturing.

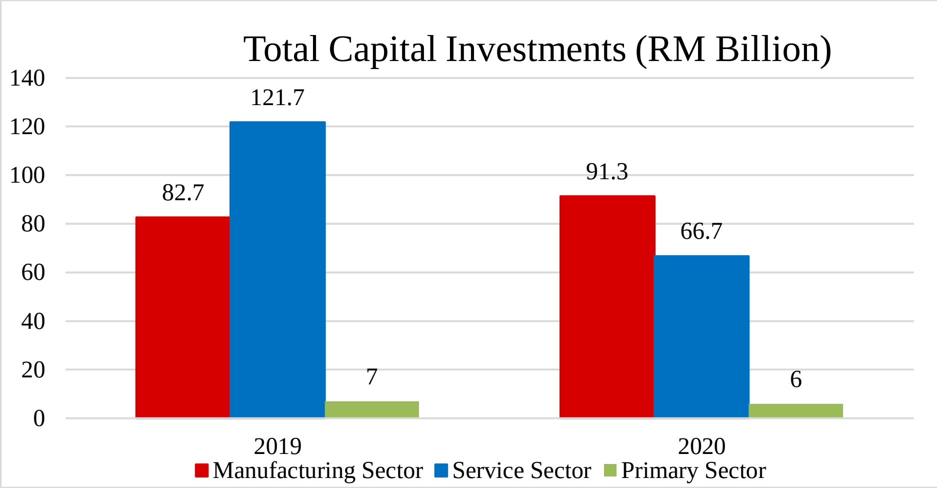


Sources: BNM (2021); DoSM (2021a)

Figure 1.5 Malaysia GDP growth by economic sectors in 3Q and 4Q of 2020

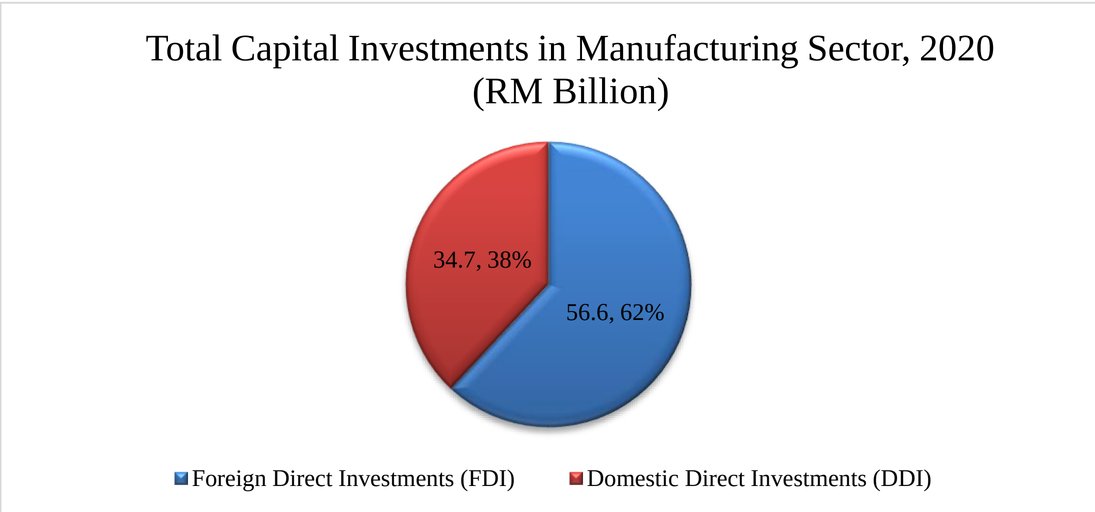
International trade is important to Malaysia’s growth and industrialisation. Malaysia has signed Free Trade Agreements with many countries and territories all over the world. In 2019, manufacturing products contributed 85% of Malaysia’s total trade volume, with electronics recorded as the largest export category (Asia Perspective, 2020). Despite the threat of global health crisis, the global demand on electrical and electronics products has driven the positive growth for Malaysia’s trade performance in the second half of 2020 and the first half of 2021 (BNM, 2021; Malaysia External Trade Development Corporation, 2021).

Rapid industrialisation in Malaysia drew substantial investments from both international and domestic investors. Malaysia had approved RM91.3 billion of investments across 1,049 projects in the manufacturing sector in 2020, recorded RM8.6 billion higher than in 2019, as presented in Figure 1.6 (MIDA, 2020b). Furthermore, Foreign Direct Investments (FDI) accounted for 37% of the total capital investments (RM34.7 billion), while Domestic Direct Investments (DDI) accounted for 62% of the total capital investments (RM56.6 billion), as shown in Figure 1.7. The total approved investments in manufacturing sector for 2020 were in line with Malaysia’s move towards technology industries involving advanced technologies and professional workforce. Despite an extremely challenging economic environment, the solid manufacturing foundation, developed infrastructure, proactive government support, skilled talent, and highly diversified economy in Malaysia attracted significant investments in the manufacturing sector. These investments are projected to create more than 80, 000 new jobs across a range of industries (MIDA, 2020b).



Source: MIDA (2020b)

Figure 1.6 Total capital investments in various economic sectors (2020 / 2019)



Source: MIDA (2020b)

Figure 1.7 Total capital investments in manufacturing sector (2020)

Based on the results of biannual Business Conditions Survey in 2020, Lean Management System implementation (61%), and employee training and upskilling (49%) are the key productivity-related strategies for business recovery that most of the respondents intended to pursue in the first half of 2021 (FMM, 2020). Furthermore, in terms of technology-related strategy, automation is the most popular, with 59% of respondents planning to implement in the first half of 2021, followed by digitalisation

(41%) (FMM, 2020). The digitalisation of data provides quick response for problem-solving and cooperative business environments. Therefore, implementation of LP and Industry 4.0 Technologies are the critical strategies for speedy business recovery.

1.4 Problem Statements

Many companies are still figuring out on how to incorporate Industry 4.0 high-tech activities into their operations (Sanders et al., 2016; Tortorella et al., 2019b). The positive growth of manufacturing companies was fuelled by enhancement in technological efficiency (Margono et al., 2011). However, Malaysia is still at the preliminary stage to incorporate Industry 4.0 Technologies in manufacturing industry (Ooi et al., 2018). Fear of failure, lower technological intensity, limited investment capital, and lack of technological expertise are the factors that curtail Industry 4.0 Technologies adoption, notably Small Medium Enterprises (SMEs) in manufacturing industry (Nor-Aishah et al., 2020; Tortorella et al., 2019b). Therefore, this study intends to examine the relationship between Industry 4.0 Technologies Adoption as mentioned in Figure 1.3 and LP due to the lack of empirical study in literature.

Despite provides sustainable economic growth and improves living standards of people, manufacturing industry is one of the dominant contributors in environment degradation (Sundram et al., 2017). Manufacturing industry required the uses of natural resources, energy, and water for industrial activities. Gas emissions and water pollution are the negative consequences of industrial activities endangering the environment and leading to climate change (Chen et al., 2020). In addition, one of the LP dimensions, JIT delivery that used for inventory management requires smaller and more frequent deliveries, increased the amount of transportation and long vehicles journeys, resulting in pollution generation which has negative environmental effects

(Bandehnezhad et al., 2012). Hence, a balance between driving economic growth, high quality of people living, and environmental conservation in manufacturing industry is critical to investigate. It is necessary to integrate economic, social, and environmental dimensions into a sustainable organisational performance (SOP) variable.

The complete set of LP dimensions in company's end-to-end processes, from internal processes to the whole value chain of customer and supplier integration, has not been investigated. Therefore, a set of 10 LP dimensions should be investigated holistically to measure overall SOP. To the best of our knowledge, there are no studies in the literature that empirically investigate relationships between LP, Industry 4.0 Technologies Adoption, and SOP in Malaysia. This study motivated to fill up the gap by investigating the effects of a complete set of LP dimensions on SOP dimensions (economic, social, and environmental) by considering Industry 4.0 Technologies Adoption as a moderator.

1.5 Research Objective

This study constructed a research framework to study the casual relationships among LP, Industry 4.0 Technologies Adoption, and SOP. With reference to the problem statement, the objective of this study is to examine the moderating role of Industry 4.0 Technologies Adoption in the relationship between LP and SOP in manufacturing industry.

1.6 Research Question

Based on the background of study and problem statement discussed in the preceding sections, the research question for this study is "Does Industry 4.0 Technologies Adoption moderates the relationship between LP and SOP?".

1.7 Significance of the Study

This research further takes consideration into the research area of LP, Industry 4.0 Technologies Adoption, and SOP in Malaysia manufacturing industry. This research attempted to add new knowledge and understanding on how holistic practices of LP led to SOP.

A research framework is developed by linking the independent variables of 10 LP dimensions adapted from both Tortorella et al. (2020) and Kamble et al. (2020) influencing the dependent variable of SOP adapted from Kamble et al. (2020) in manufacturing companies. LP is an effective production system (Yang et al., 2020) while the SOP that generated from Triple Bottom Line Theory is to measure the sustainable performance of an organisation (Gimenez et al., 2012). Moreover, this study provides clearer insights that LP deployment is critical in improving companies' sustainable performance through the significant direct effect of LP on SOP.

Desirably, a moderating role of Industry 4.0 Technologies Adoption on the relationship between LP and SOP is empirically introduced in this research. This study sheds the light on importance of Industry 4.0 Technologies Adoption as a moderator in improving SOP. The moderating variable of Industry 4.0 Technologies is described as a third variable that affects the direction and/or strength of the relationship between LP and SOP. As a result, this study contributes to a deeper understanding of the relationships between integration of LP and Industry 4.0 Technologies Adoption, and their implications toward SOP.

1.8 Definition of Key Terms

The key terms are defined for better understanding in this thesis. Table 1.1 presents definition of key terms used in the thesis.

Table 1.1 Definition of key terms

Key Terms	Definition
Lean Production	An integrated socio-technical system seeks to eliminate wasteful activities while also improving productivity by simultaneously minimising variability of internal process, supplier, and customer (Shah & Ward, 2007).
Industry 4.0 Technologies Adoption	Refers to a collection of convergent and evolving digital technologies being used to direct the development of smart and complex manufacturing systems, and the mass production of high-customised products within the fourth industrial revolution (Tortorella et al., 2019b).
Sustainability	Development that satisfies present needs without compromising the ability of future generations to fulfill their own needs (Brundtland & Khalid, 1987).
Sustainable Organisational Performance	Companies are expected to perform on 3 sustainable dimensions: economic, social, and environmental, which are collectively referred to as the triple bottom line, to meet the different needs of various stakeholders (Kamble et al., 2020).
Economic Performance	Focuses on maximising financial benefits return to the shareholders through profits, sales, revenue, and return on investment by adding value or reducing cost during production process (Margherita & Braccini, 2020).
Social Performance	Focuses on practical, beneficial, and equitable practices to the employees, the local community or society, and the area in which a company operates (Sajan et al., 2017).
Environmental Performance	Focuses on avoiding negative impact of industrial activities towards environment by rationalising amount of natural resources or energy consumption, and reducing emissions through production process (Hubbard, 2009).

1.9 Organisation of the Remaining Chapters

This thesis is organised and written into 5 chapters. In Chapter 1, introduction and background of the study are described to provide insights. Direction of the study is driven by problem statements, research objective, and research question. Significance of the study and definition of key variables are also outlined in Chapter 1. Chapter 2 reviews related literatures by previous researchers. Research framework and hypotheses will be formed in Chapter 2. Chapter 3 discusses on the research methodology used in conducting the research. Chapter 4 presents the data analysis and summary of the results. The data is analysed and interpreted by using appropriate statistical analysis techniques. In Chapter 4, hypotheses developed in Chapter 2 are tested. Chapter 5 reviews and discusses the major findings, implications, limitations of the study, and conclusion. The conclusion chapter gives some suggestions and recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of literature that is related to the research objective of the study. Section 2.2 reviews literature related to manufacturing industry. Section 2.3 to Section 2.5 consists of review on the literature of LP, Industry 4.0 Technologies Adoption, and SOP, respectively. Next, the analysis of previous works on Lean Production Theory and Triple Bottom Line Theory are covered in Section 2.6. An overview of research framework is discussed in Section 2.7, followed by hypotheses development in Section 2.8.

2.2 Manufacturing Industry

Manufacturing is defined as the combination of machinery, tools, human resources, biological or chemical processing, and energy in a processing of products (Groover, 2020). All manufacturing companies, regardless product type, production process, or company size, are required to monitor the material flow from suppliers to customers, through value-adding activities and distribution networks (Stevens, 1989). Manufacturing is the process of converting raw materials, components, or parts into finished products on a wide scale production using conventional or cutting-edge methods to satisfy customer needs (Akinlabi et al, 2021). The finished products are often supplied to other manufacturers for the assembly of additional complicated products, to wholesalers, or to customers directly (Akinlabi et al., 2021). Figure 2.1 presents the manufacturing companies' end-to-end processes, which starts at material procurement from suppliers and ends at final product delivers to the customer.

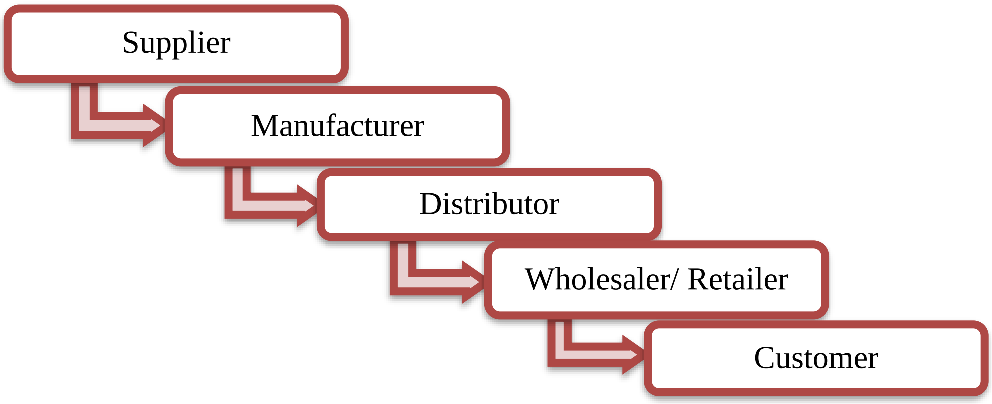
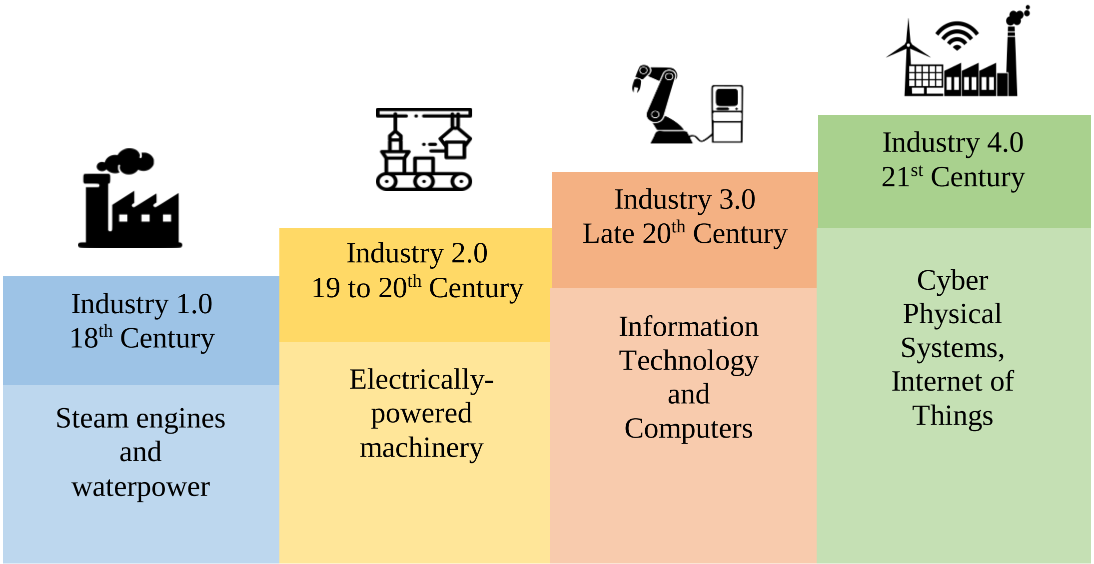


Figure 2.1 Manufacturing companies' end-to-end processes

Manufacturing industry has evolved from the introduction of steam engines and waterpower in Industry 1.0, followed by using electrically powered machinery for mass production in Industry 2.0, to the use of information technology (IT) and computers for automation in Industry 3.0 (Akinlabi et al., 2021; Ghobakhloo, 2018; Pagliosa et al., 2021). When comes to the Industry 4.0, manufacturing processes are becoming more complex, automated, and sustainable, allowing manpower to operate machines more easily, effectively, and consistently to react rapidly to dynamic market demands and conditions (Lu & Xu, 2018). Figure 2.2 presents the industrial revolution of the manufacturing sector from Industry 1.0 (18^{th} century) to Industry 4.0 (21^{st} century).

Industry 4.0 is regarded as the subset of 4IR. According to Sung (2018), the term 4IR has been applied to key technological innovations over time, and it indicates a systemic transformation that affects civil society, governance systems, and human identity in addition to economic and manufacturing aspects. Industry 4.0, on the other hand, is distinct from the 4IR in terms of scope because it focuses on automation and data exchange in manufacturing sector particularly (EPU, 2021a). Noting that 4IR is different from Industry 4.0. This study is using the terms "Industry 4.0" for the 11 pillars of advanced technologies in the manufacturing context.



Sources: Ghobakhloo (2018); Lu and Xu (2018); Akinlabi et al. (2021); Pagliosa et al. (2021)

Figure 2.2 Industrial revolution in the manufacturing sector

In Malaysia, the manufacturing industries are classified into resource-based or non-resource-based (Abdul-Aziz et al., 2000). Resource-based refers to the industries that highly reliant on abundant natural resources exploitation while non-resource-based refers to the industries that produce more dynamic and high value-added products using sophisticated technologies (Batista, 2004; Reinhardt, 2000; Tompson, 2005). Companies in the food, leather, non-metallic minerals, rubber, wood, palm oil, and petroleum are examples of resource-based industries (Abdul-Aziz et al., 2000; Lebdioui et al., 2020). Non-resource-based industries include the chemical, electrical and electronics, machinery and engineering, textile, transport equipment, and plastic companies (Abdullah, 1995; Abdul-Aziz et al., 2000). On top of the two categories above, heavy industries have emerged recently. Cement, steel, and automotive manufacturing are among the heavy industries (Abdullah, 1995).

The contributions of manufacturing industry to the national economy are huge in wide range, including GDP, exports, employment, return on investment, labor productivity, and wages (Karim et al., 2008; Rasiah et al., 2015). The areas of innovation, science, computer and IT, engineering and mathematics, and national security are linked in an iconic relationship with manufacturing (Wang, 2018). Manufacturing also plays an important role by accounting for one-quarter of employment globally (Singh et al., 2017).

As a result, several manufacturing paradigms have been implemented to assist manufacturers in achieving these goals, including lean and smart manufacturing (Pagliosa et al., 2021). The new threats or problems that arise unexpectedly placed manufacturing industry in a highly diversified and challenging business environment. Manufacturing companies are being pulled to develop novel management strategies by using advanced technologies in producing products or services quickly, cost-effectively, and in a high quality manner (Lu & Xu, 2018). Moreover, manufacturing costs reduction, waste minimisation, and customer loyalty are also important for manufacturing companies to achieve the next level of organisational performance (Zahraee, 2016).

The role of manufacturing industry is linked with all human activities in modern society, and provides essential value-added products or services to generate human health, safety, quality of life, and well-being (Abubakr et al., 2020). Additionally, manufacturing operations that ruining the environment must take accountability for protecting the natural environment to supports life on earth for future generations (Habidin et al., 2013; Nor-Aishah et al., 2020). Given that manufacturing industries are responsible for the manufacture products that preserve environment, improve human life quality and the global economy, it is critical to examine manufacturing industry from a sustainability perspective.

Table 2.1 Comparison between LP manufacturing, smart manufacturing, and additive manufacturing

Characteristics	**Manufacturing Paradigm**		
Type	Lean Production Manufacturing	Smart Manufacturing	Additive Manufacturing
Human intervention	High	Low	Low
Technology implementation	Medium	High	High
Production	Customisation	Customisation	Customisation
Responsiveness	High	High	High
Productivity	High	High	High
Flexibility	High	High	High
Cost-saving	High	High	High
Waste consumption	Low	Low	Low

Table 2.1 displays the comparison of characteristics between three manufacturing paradigms. The three different manufacturing paradigms, namely LP manufacturing, smart manufacturing, and additive manufacturing are intended to improve manufacturing end-to-end processes but applying different tools to achieve the goals. The concept of LP manufacturing is striving to be more responsive to customer demand and generate products or services at the lowest cost through waste elimination activities (Bhamu & Sangwan, 2014). Apart from that, the smart manufacturing is defined as an integrated, automated, and digitalised system driven by flexible manufacturing processes that allows real-time responsiveness to changing conditions in the market (Lu et al., 2016; Kusiak, 2018). Other than that, the additive manufacturing is a flexible technology using software and 3D scanners to generate a customised product that meet the customer requirements in a shorter period and lower cost (Haleem & Javaid, 2019). LP manufacturing that highly involving human to integrate with JIT,

TPM, and other techniques for process and product improvement is different with another two manufacturing paradigms (Tortorella et al., 2019b). Smart manufacturing and additive manufacturing are heavily reliant on cutting-edge technologies to address production issues with a minimum level of human intervention (Tortorella et al., 2019a). Conversely, there are few similarities between the three manufacturing paradigms, which are productivity and flexibility improvement, cost-saving, waste reduction, and most importantly, the ability to swiftly respond to customisation requirements (Bhamu & Sangwan, 2014; Huang et al., 2013; Kang et al., 2016; Qu et al., 2019). Notably, additive manufacturing is a critical element in smart manufacturing for facilitating the mass customisation of products through sensor systems (Mehrpouya et al., 2019). Thus, both smart manufacturing and additive manufacturing share common characteristics.

2.3 Lean Production (LP)

LP is a system uses to produce more products in manufacturing process by using less of everything in the input as compared with mass production (Johan et al., 2019). LP refers to a series of strategies focused on continuous process improvement to eliminate non-value added activities in an organisation (Ruiz-Bentez et al., 2018; Tiwari et al., 2020). There are various terms used by researchers, such as “Lean Manufacturing Practices” (Kamble et al., 2020; Sant’Anna et al., 2017), “Lean Practices” (Centobelli et al., 2019), “Lean Process” (Huo et al., 2019), or “Lean” (Alkhoraif et al., 2019). All are referring to the LP, which is defined by the original authors, Shah and Ward (2007). In the context of this thesis, the term “Lean Production” is used.

The LP is described as a hybrid of craftsmanship and mass production by combining the benefits of variety in craft production and low prices in mass production (Womack et al., 2007). In other words, LP aims to provide mass-customisation products by avoiding both the high costs of craft production and the rigidity and standardisation