
## Faculty of Manufacturing Engineering



# SUSTAINABLE MANUFACTURING PRACTICE AND SUSTAINABILITY PERFORMANCE MEDIATED BY INNOVATION PERFORMANCE

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**Doctor of Philosophy**

**2015**

# SUSTAINABLE MANUFACTURING PRACTICE AND SUSTAINABILITY PERFORMANCE MEDIATED BY INNOVATION PERFORMANCE

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**A thesis submitted**
**in fulfillment of the requirements for the degree of Doctor of Philosophy**



**Faculty of Manufacturing Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2015**

# APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

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# DEDICATION

To my beloved husband, sons and parents

# ABSTRACT

Sustainable manufacturing (SM) strategies have drawn attention derived from increasing global concerns on sustainability issues such as the scarcity of natural resources, rapid environmental destruction and unequal balance of social equities. The concept of sustainability has dramatically extended the goals of businesses, traditionally solely focused on operational efficiency and economic returns, to include environmental and social benefits. Embracing the idea of the triple bottom line approach, firm performance is assessed based on three criteria namely economic, environmental and social sustainability. The importance of environmental management and socially responsible practices for enhancing sustainability performance (SP) at a firm level has been widely acknowledged and extensively reported in the extant literature. While some researchers found a positive and significant impact of sustainable manufacturing practice (SMP) on predicting SP, there were some other researchers who failed to prove the significant relationship between these two variables. The inconsistent result of SMP-SP linkage might be due to the reason that the contextual elements of SMP and SP have not been well established. Insufficient statistical evidence to corroborate the significant impact of SMP on SP demonstrates that there may be a more complex relationship between SMP and SP. Since the significant relationship of innovation performance (IP) with SMP and SP has been found in some previous studies, there is a possibility that IP mediate the SMP-SP linkage. The objectives of this study are to identify the level of SMP, SP and IP among Malaysian manufacturing firms, to analyze the direct and indirect effect of SMP on SP, and eventually to propose a validated framework indicating the interrelationships between SMP, SP and IP. Using the theories of stakeholder and resource-based view (RBV) of a firm, integrating with prior research on sustainability, SM and innovation, a theoretical model depicting the interrelationships between SMP, IP and SP has been developed in this study. A series of hypothesized relationships were tested through PLS-SEM approach by using survey data collected from 150 firms. The results reveal that internal SMP has a positive and significant impact on economic sustainability, and both types of SMP (internal SMP and external SMP) have significant impact on environmental and social sustainability. While both types of SMP have mediated effect on social sustainability through organizational innovation, process innovation is the single significant mediator for internal SMP-economic sustainability linkage and both product and process innovations are the significant mediators for external SMP-economic sustainability linkage. The study indicates that the level of implementation of SMP is moderate to considerable extent, and economic benefits are still the dominant factors on embracing SMP compared to the others. The results also demonstrate that Malaysian manufacturers are able to gain better IP, reflecting that increasing innovation capabilities might be of high importance to the firms. While offering significant theoretical contribution by enhancing the SM, innovation and sustainability body of knowledge, the findings of this study are beneficial for industrial practitioners through better understanding of the contextual elements of SMP, IP and SP which would support their continuous improvement.

# *ABSTRAK*

*Strategi pembuatan mampan (SM) telah mendapat perhatian hasil daripada kebimbangan global terhadap isu kelestarian seperti kekurangan sumber asli, kemusnahan alam sekitar dan ketidakseimbangan ekuiti sosial. Konsep pembangunan mampan telah meluaskan matlamat perniagaan iaitu bukan sahaja memberi tumpuan kepada kecekapan operasi dan pulangan ekonomi tetapi juga mengambil kira faedah kepada alam sekitar dan sosial. Menyokong pendekatan "triple bottom line", prestasi firma dinilai berdasarkan kepada kemampanan ekonomi, kelestarian alam sekitar dan kemampanan sosial. Kepentingan amalan yang menitikberatkan aspek tanggungjawab sosial dan pengurusan alam sekitar terhadap peningkatan prestasi mampan (SP) telah diakui dan dilaporkan secara meluas dalam literatur. Walaupun beberapa penyelidik mendapati bahawa amalan pembuatan mampan (SMP) memberi kesan positif dan signifikan kepada SP, terdapat beberapa penyelidik lain yang gagal membuktikan hubungan tersebut secara signifikan. Keputusan yang tidak konsisten dalam hubungan SMP-SP mungkin disebabkan oleh masalah dalam mendefinisikan konteks SMP dan SP. Kekurangan bukti statistik menyokong hubungan signifikan di antara SMP dan SP menunjukkan kemungkinan wujudnya hubungan yang kompleks di antara kedua-dua pembolehubah. Mengambil kira dapatan kajian lepas mengenai hubungan signifikan prestasi inovasi (IP) dengan SMP dan SP, terdapat kemungkinan bahawa IP adalah pengantara bagi hubungan SMP-SP. Objektif kajian ini adalah untuk mengenal pasti tahap SMP, SP dan IP di kalangan firma pembuatan di Malaysia, menganalisis kesan secara langsung dan tidak langsung SMP terhadap SP, dan mencadangkan rangka kerja yang telah disahkan yang menunjukkan hubungan di antara SMP, SP dan IP. Menggunakan teori pihak berkepentingan dan RBV, diintegrasikan dengan penyelidikan terdahulu, model teori menggambarkan hubungan di antara SMP, IP dan SP dibangunkan dalam kajian ini. Melalui teknik PLS-SEM, satu siri hubungan hipotesis diuji dengan menggunakan data kajian yang dikumpul daripada 150 firma. Keputusan menunjukkan SMP dalaman mempunyai kesan positif dan signifikan ke atas kemampanan ekonomi, dan kedua-dua jenis SMP (SMP dalaman dan luaran) mempunyai kesan ketara kepada kelestarian alam sekitar dan kemampanan sosial. Sementara itu, kedua-dua jenis SMP mempunyai kesan tidak langsung ke atas kemampanan sosial melalui pemboleh ubah intervensi inovasi organisasi. Inovasi proses pula adalah pemboleh ubah intervensi tunggal untuk hubungan kemampanan SMP-ekonomi dalaman manakala kedua-dua produk dan proses inovasi adalah pembolehubah intervensi yang signifikan bagi hubungan SMP luaran-ekonomi kemampanan. Selain itu, dapatan kajian menunjukkan tahap pelaksanaan SMP yang sederhana dan baik, manfaat ekonomi terus menjadi faktor pendorong dominan kepada perlaksanaan SMP, dan pencapaian prestasi yang baik dalam IP mencerminkan bahawa peningkatan keupayaan inovasi mungkin menjadi keutamaan kepada firma. Selain menyumbang kepada pengembangan pengetahuan dalam bidang SM, inovasi dan kelestarian, dapatan kajian ini memberi manfaat kepada pengamal industri melalui pemahaman yang lebih baik mengenai konteks SMP, IP dan SP yang akan menyokong kepada penambahbaikan yang berterusan.*

## ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful. I would like to extend my deepest gratitude and thanks to Allah the Almighty for giving me excellent health and energy to complete my research.

I would like to express my gratitude to everyone who contributes to the completion of this research. Special thanks go to my main supervisor, Prof. Dr. Mohd. Razali Muhamad, and co-supervisor, Dr. Zuhriah Ebrahim, for their valuable guidance, ideas and encouragement throughout the entire research process. Without their assistance and continued support, I would not be able to complete this thesis as presented here.

My acknowledgments are also dedicated to Ministry of Education Malaysia for financial support and my beloved employer, Universiti Utara Malaysia (UUM), for giving me the chance to pursue my PhD in the Universiti Teknikal Malaysia Melaka (UTeM). I am also indebted to the respondents in this study for their time and willingness to share valuable information.

My sincere appreciation also extends to the scholars and administrative staff in UTeM and UUM who gave countless constructive suggestions and administrative assistance. I would further like to thank all my friends, colleagues and others who have provided assistance at various occasions. Last but not least, very special thanks to my husband, my kids, my parents and my mother-in-law for their limitless encouragement, patience, love and support during the entire process.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| 3R | - | Reduce, reuse, recycle |
| 6R | - | Reduce, reuse, recycle, recover, redesign, remanufacture |
| APEC | - | Asia-Pasific Economic Cooperation |
| AVE | - | Average variance extracted |
| BNM | - | Bank Negara Malaysia |
| CB-SEM | - | Covariance based structural equation modeling |
| CEO | - | Chief executive officer |
| CFA | - | Confirmatory factor analysis |
| CI | - | Confidence interval |
| CMB | - | Common method bias |
| $CO_2$ | - | Carbon dioxide |
| CR | - | Composite reliability |
| CSR | - | Corporate social responsibility |
| EFA | - | Exploratory factor analysis |
| EMS | - | Environmental management systems |
| EPA | - | Environmental Protection Agency |
| Ext1 | - | Supplier relation |
| Ext2 | - | Customer relation |
| Ext3 | - | Community relation |
| Ext4 | - | Closed-loop production |

| | | |
|---|---|---|
| Ext5 | - | Industrial relation |
| FMM | - | Federation of Malaysian Manufacturers |
| GDP | - | Gross domestic product |
| GHG | - | Greenhouse gases |
| GLC | - | Government-linked companies |
| IBM SPSS | - | Statistical Package for the Social Sciences |
| IEA | - | International Energy Agency |
| ILO | - | International Labor Organization |
| IMF | - | International Monetary Fund |
| Int1 | - | Cleaner production |
| Int2 | - | Eco-efficiency |
| Int3 | - | Employee relation |
| IP | - | Innovation performance |
| IP1 | - | Product innovation |
| IP2 | - | Process innovation |
| IP3 | - | Organizational innovation |
| IP4 | - | Marketing innovation |
| ISO | - | International Organization for Standardization |
| JV | - | Joint venture |
| LC | - | Local company |
| MNC | - | Multinational corporation |
| OECD | - | Organization for Economic Co-operation and Development |
| PBDE | - | Dipheny polybrominated ether |
| PLS-SEM | - | Partial least squares structural equation modeling |
| PRC | - | The People's Republic of China |

| | | |
|---|---|---|
| R&D | - | Research and development |
| RBV | - | Resource-based view |
| SD | - | Sustainable development |
| SEM | - | Structural equation modeling |
| SME | - | Small and medium enterprise |
| SMP | - | Sustainable manufacturing practice |
| SOCSO | - | Social Security Organization |
| SP | - | Sustainability performance |
| SP1 | - | Economic sustainability |
| SP2 | - | Environmental sustainability |
| SP3 | - | Social sustainability |
| TBL | - | Triple bottom line |
| TQM | - | Total quality management |
| UNEP | - | United Nations Environment Programme |
| UK | - | United Kingdom |
| US | - | United States |
| VIF | - | Variance inflation factor |
| WBCSD | - | World Business Council for Sustainable Development |
| WCED | - | World Commission on Environment and Development |
| WTO | - | World Trade Organization |

## LIST OF PUBLICATIONS

Hami, N., Muhamad, M.R. and Ebrahim, Z., 2014. Exploring Sustainable Manufacturing Practices and Sustainability Performance among Malaysian Manufacturing Firms. In *International Symposium on Research in Innovation and Sustainability 2014*, Melaka, Malaysia, 15-16 October 2014. Universiti Teknikal Malaysia Melaka.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Preliminary

The business environment has changed significantly since the last decades. Efforts toward globalization have increased due to an increase in connectivity and interdependence among different markets and business niches around the world. Globalization, which is the process of international integration, has become the propeller of global economic growth (Kim, 2010). International trade has managed to record positive growth annually for the past five years (2005-2010), with an annual average growth of more than 7% (WTO, 2011).

Table 1.1 shows the data of global merchandise trade dating from the middle of the 20th century. The data highlighted an increase pattern for both merchandise exports as well as imports. More remarkably, the value of global merchandise exports and imports has increased significantly from US$59 billion and US$62 billion in 1948 to US$14,851 billion and US$15,077 billion in 2010, respectively (WTO, 2011). This is an indicator which signaled how developed and developing countries are able to create competitive advantages by opening their economies to the global stage. Impressive evidence could be seen from the favorable economic performance exhibited by one of Asia's own economic giants, The People's Republic of China (PRC).

PRC is the second largest economy in the world, closely behind the United States (US) with a nominal gross domestic product (GDP) of US$8,229.4 billion in 2012 and an estimated US$9,181.4 in 2013 (IMF, 2014). It is the fastest-growing major economy in the

world, with growth rates averaging 10% over the past 30 years. Its share in the global growth from 1995 to 2002 was estimated at 25%, compared to 20% in the US (Kim, 2010). Besides PRC, other developing countries in Asia have also experienced rapid economic growth. For example, in 2013 alone, GDP increased by 4.7% in Malaysia, 2.9% in Thailand, 5.8% in Indonesia and 7.2% in Philippines (IMF, 2014), displayed in Table 1.2.

Nevertheless, various conflicts of interest emerged between the economic profit originating from industrialization and the accompanying adverse effects due to severe pollution and destruction of natural resources caused by such industrial activities. For instance, rapid industrial development in PRC since the 1980's as a result of economic reformed stirred concern. PRC, which emitted 5.92 tons per capita of carbon dioxide ($CO_{2)}$ or approximately 25% of global emissions in 2011, has been the biggest emitter of $CO_2$ in the world since 2006 (IEA, 2013). There is a strong view that the level of $CO_2$ and other greenhouse gases (GHG) such as methane, nitrous oxide and a number of gases that are created from industrial processes is rising (Rajemi, 2010). Although the flow of carbon emissions is not harmful to the public immediately, contrasting with the other polluting gases, it is a major contributor to climate change problems.



Recognizing the importance of economic development to society, creation of material wealth and prosperity has been a primary goal for many countries. However, is the rapid industrial development really managed to improve the social well being? As reported by the International Labor Organization (ILO), on average, 6,300 people die globally as a result of occupational accidents or work-related diseases each day. Workers suffer from 317 million accidents happen while working annually, together with occupational diseases, resulting more than 2.3 million deaths per year (ILO, 2014). Hence, the urgency of further scrutiny and action to ensure survival of human life is needed.

Table 1.1 Global Merchandise Trade

| Year | 1948 | 1953 | 1963 | 1973 | 1983 | 1993 | 2003 | 2010 |
|---|---|---|---|---|---|---|---|---|
| Value (Billions US$) | | | | | | | | |
| Merchandise exports | 59 | 84 | 157 | 579 | 1838 | 3676 | 7377 | 14851 |
| Merchandise imports | 62 | 85 | 164 | 594 | 1882 | 3786 | 7695 | 15077 |

Source: World Trade Organization, International Trade Statistics 2011

Table 1.2 GDP Growth for Selected Countries

| Country | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| GDP at constant prices (% change) | | | | | | | | | |
| United States | 3.4 | 2.7 | 1.8 | -0.3 | -2.8 | 2.5 | 1.8 | 2.8 | 1.9 |
| Japan | 1.3 | 1.7 | 2.2 | -1.0 | -5.5 | 4.7 | -0.5 | 1.4 | 1.5 |
| United Kingdom | 3.2 | 2.8 | 3.4 | -0.8 | -5.2 | 1.7 | 1.1 | 0.3 | 1.8 |
| South Korea | 4.0 | 5.2 | 5.1 | 2.3 | 0.3 | 6.3 | 3.7 | 2.0 | 2.8 |
| Hong Kong | 7.4 | 7.0 | 6.5 | 2.1 | -2.5 | 6.8 | 4.8 | 1.6 | 2.9 |
| Taiwan | 4.7 | 5.4 | 6.0 | 0.7 | -1.8 | 10.8 | 4.2 | 1.5 | 2.1 |
| Singapore | 7.4 | 8.9 | 9.0 | 1.9 | -0.6 | 15.1 | 6.0 | 1.9 | 4.1 |
| Thailand | 4.6 | 5.1 | 5.0 | 2.5 | -2.3 | 7.8 | 0.1 | 6.5 | 2.9 |
| Philippines | 4.8 | 5.2 | 6.6 | 4.2 | 1.1 | 7.6 | 3.6 | 6.8 | 7.2 |
| Indonesia | 5.7 | 5.5 | 6.3 | 6.0 | 4.6 | 6.2 | 6.5 | 6.3 | 5.8 |
| Malaysia | 5.0 | 5.6 | 6.3 | 4.8 | -1.5 | 7.4 | 5.1 | 5.6 | 4.7 |

Source: International Monetary Fund, World Economic Outlook Database, April 2014

## 1.2 Sustainability in manufacturing

Although remarkable economic achievement has contributed to human development and reduced poverty in Malaysia, the impacts of rapid environmental changes raise doubts as to its sustainability and inter-generational equity (Hezri and Hasan, 2006). In recent decades, the country faces new challenges related to the sustainability due to the increasing of the scarcity of resources, the rapid deterioration of the global environment, and human beings pursuit of a higher quality of life. With the increasing of the depletion of natural resources of the earth, firms are looking for better efficiency in managing their resource needs.

Manufacturing is one of the key economic sectors in Malaysia which recorded positive annual growth, accounted for 24.2% of GDP in 2012 as shown in Table 1.3. The main impetus for this favorable performance were petroleum, chemical, plastic and rubber products (29.9% shares) as well as the rebound in transport equipment and other manufactured products. Meanwhile, electrical and electronics products were the second largest contributor with 24.5% of shares (Department of Statistics Malaysia, 2013).



Key indicators of the manufacturing sector registered a positive growth in 2010, as shown in Table 1.4. The value of gross output grew by RM181.0 billion in the five years, resulting in an annual compounding growth rate of 5% between 2005 and 2010. During the same period, the other key indicators of manufacturing sector include intermediate input, value added, fixed assets, and employment followed the same trend, with an increase of 4.4%, 7.6%, 2.0% and 1.6%, respectively (Department of Statistics Malaysia, 2012).

Unfortunately, despite the impressive performance exhibited by the annual GDP and the main indicators of the manufacturing sector, the number of accidents (including occupational diseases) that were reported to the Ministry of Labor and Social Security Organization (SOCSO) is also quite high. A total of 61,552 cases were reported in 2010, an

Table 1.3 Percentage Share of GDP by Economic Activities

| Economic activity | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011[e] | 2012[p] |
| GDP at current prices (% share) | | | | | | | | |
| Agriculture | 8.3 | 8.6 | 10.0 | 10.0 | 9.2 | 10.4 | 11.8 | 10.1 |
| Mining and quarrying | 13.3 | 13.7 | 13.3 | 15.6 | 11.4 | 10.9 | 10.4 | 10.4 |
| Manufacturing | 27.5 | 27.6 | 26.1 | 24.6 | 23.8 | 24.5 | 24.3 | 24.2 |
| Construction | 3.0 | 2.8 | 2.8 | 2.7 | 3.3 | 3.4 | 3.4 | 3.9 |
| Services | 46.8 | 46.4 | 46.9 | 46.1 | 51.3 | 49.9 | 49.1 | 50.4 |
| Import duties | 1.2 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |

Notes:
[e] estimate data
[p] preliminary data

Source: Department of Statistics Malaysia, 2013



Table 1.4 Key indicators of manufacturing sector for 2005 and 2010

| Key indicators | 2005 | 2010 | Average annual growth (%) |
|---|---|---|---|
| Gross output (RM billion) | 655.5 | 836.5 | 5.0 |
| Intermediate input (RM billion) | 537.3 | 665.8 | 4.4 |
| Value added (RM billion) | 118.2 | 170.7 | 7.6 |
| Value of fixed assets (RM billion) | 190.9 | 210.4 | 2.0 |
| Employment (persons) | 1,675,163 | 1,812,360 | 1.6 |

Source: Department of Statistics Malaysia, 2012