

**AN EMPIRICAL STUDY ON THE CONTRIBUTION OF LEAN PRACTICES TO
SUSTAINABLE MANUFACTURING:**

THE ROLE OF LEAN CULTURE AS MODERATOR

By

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DECLARATION

I hereby declare that the project is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at USM or any other institutions.

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KAJIAN EMPIRIKAL MENGENAI AMALAN LEAN TERHADAP PENGELUARAN LESTARI: PERANAN BUDAYA LEAN SEBAGAI MODERATOR

ABSTRAK

Saat ini, masalah kelestarian menerima tahap peningkatan perhatian tinggi di peringkat global dan tempatan yang akhirnya mengarah pada pertanyaan tentang bagaimana untuk mengintegrasikan kelestarian dengan operasi perniagaan dan strategi. Walaupun pentingnya, pengeluaran *Lean* dalam mengurangkan masalah pengeluaran berterusan dan memberikan manfaat persekitaran, ekonomi dan sosial kepada organisasi, sedikit yang diketahui tentang pengaruh amalan ini terhadap kelestarian triple bottom line. Tujuan penyelidikan ini adalah untuk mengetahui pengaruh amalan *Lean* di bidang fungsi yang berbeza terhadap prestasi syarikat perkilangan pengeluaran kelestarian. Selain itu, kajian ini mengkaji pengaruh penyederhanaan budaya *Lean* pada hubungan antara amalan *Lean* dan prestasi pengeluaran berterusan. Untuk mencapai tujuannya, kajian ini menggunakan kajian soal selidik terhadap 445 kilang pengeluaran di wilayah utara Malaysia. Hanya 101 soal selidik boleh digunakan untuk kajian seterusnya. Keputusan kaji selidik menunjukkan bahawa amalan *Lean* berkaitan dengan bidang fungsi proses dan peralatan, sumber manusia, rekabentuk produk dan kepuasan pelanggan berpengaruh positif terhadap hasil alam sekitar. Keputusan kajian juga mendedahkan bahawa sumber daya manusia, rekabentuk produk dan amalan hubungan pembekal berpengaruh positif terhadap hasil ekonomi dan proses dan peralatan, perancangan pengeluaran dan kawalan, hubungan pembekal dan amalan hubungan pelanggan berpengaruh positif terhadap hasil-hasil social. Penyelidikan ini mendapati kesan sederhana positif dari budaya *Lean* pada hubungan antara perancangan dan kawalan pengeluaran dan hasil persekitaran dan hubungan pelanggan dan hasil ekonomi. Budaya *Lean* juga menyederhanakan pengaruh rekabentuk produk, hubungan

pembekal dan amalan hubungan pelanggan terhadap hasil sosial. Akhirnya, implikasi keputusan dan cadangan unuk kajian akan datang disertakan dalam laporan ini.

An Empirical Study on Contribution of Lean Practices on Sustainable Manufacturing: The Role of Lean Culture as Moderator

ABSTRACT

Nowadays, sustainability issues receives an increasing level of attention at both global and local levels which eventually leads to questions on how to integrate sustainability with business operations and strategy. Despite the importance of lean manufacturing in alleviating sustainable manufacturing issues and providing environmental, economic and social benefits to organizations, little is known about the effect of lean practices on triple bottom line of sustainability. The purpose of this study is to investigate the effect of lean practices in different functional areas of manufacturing firms on sustainable manufacturing performance. In addition, the study investigates the moderating effect of lean culture on the relationships between the lean practices and sustainable manufacturing performance. To attain its objectives, the study utilized mail survey to 445 manufacturing firms in northern region of Malaysia. 101 usable responses were received from the respondents. The results of the survey indicate that lean practice related to functional areas of process and equipment, human resource, product design and customer satisfaction have positive effect on environmental outcomes. The results of the study also reveals that human resource, product design and supplier relationship practices have positive effect on economic outcomes and process and equipment, manufacturing planning and control, supplier relationship and customer relationship practices have positive effect on social outcomes. This study found positive moderating effect of lean culture on relationship between manufacturing planning and control and environmental outcomes and customer relationship and economic outcomes. Lean culture also moderate the effect of product design, supplier relationship and

customer relationship practices on social outcomes. Finally, implication of the results and suggestions for future research are discussed at the end of research.

CHAPTER 1

INTRODUCTION

1.0 Introduction

News and documentation have shaped our perception of sustainability in our daily life. Issues such as global warming, the rising cost of energy and scarcity of non-renewable resources warn us that our lifestyles and business patterns are not fit with the principles of sustainability. Consequently, the need for shifting the traditional industrial model, in which natural resources considered as unlimited goods, into a more sustainable manner has been realized (Seidel, Shahbazzpour & Seidel, 2007). These issues make manufacturers to rethink and improve their production system toward a more sustainable manner and strive to achieve efficient and environmental conscious manufacturing process.

According to Organization for Economic Co-operation and Development (OECD) synthesis report (2009), manufacturing industries account for considerable part of world's consumption of resources and waste generation. Worldwide, they consumed approximately one third of total global energy which has been increased by 61% since 1971 to 2004. Likewise, 36% of global carbon dioxide (CO₂) emission are due to manufacturing industries. Since past 20 years, increasing the concerns of sustainability, put tremendous pressures on businesses to pay more attention to their environmental impact they leave behind as a consequences of their operation (Kleindorfer, Singhal & Wassenhove, 2005). Various stakeholders such as regulators, shareholders, customers and employees are requiring firms to be more responsible regarding their products and processes. Accordingly, Logamuthu and Zailani (2010) explain that green consumerism has emerged in order to encourage manufacturer to be more responsible in the manufacturing processes and delivering products.

In respond to this demand, practices such as green, eco-manufacturing, eco machining has been emerged in order to represent the products, processes and systems that address environmental concerns. However, as it is emphasized by Eltayeb (2009) and Anbumozhi and Kanda (2005), most of these adopted solutions were “end-of-the-pipe” solutions where firms try to eliminate pollution and negative environmental impact after they are created instead of implementing a proactive approach to reduce the source of waste and pollution.

Sustainable manufacturing seeks to move beyond green initiatives. Leahu-Aluas and Burstein (2010) suggested that sustainable manufacturing is more comprehensive and systematic than practices such as green, eco-manufacturing, eco-machining and clean production, because while it considers all environmental concerns such as pollution, material toxicity, and greenhouse gases (GHG) emissions, it is not just limited to those concerns. It provides broader insight by dealing with all the three components of sustainability: environment, economy and society (Pojasek, 2010). So, in order to consider a practice to be truly sustainable the three outcomes of environmental, social and economic must be examined.

Westkamper (2008) suggested that implementing the dimensions of sustainability is possible by integrating the criteria of holistic production system such as cost, time, quality with methodologies such a lean, JIT, TQM and etc. Lean manufacturing offers great opportunities for substantial performance improvement by focusing on elimination of all types of waste such as time, materials, manpower, just-in-time production methods and continuous improvement of existing work practices (Jergensen, 2008).

The main purpose of this research is therefore, to study the contribution of lean practices towards sustainable manufacturing among manufacturing companies in northern region of Malaysia. This study starts with an introductory chapter that provides a general idea about the

research topic and problem statement regarding to the study. The chapter starts with providing background of the study that includes explanation of environmental issues or concerns at the global as well as local (Malaysian) level. Further on, the discussion will be extended toward discussing the problem of the study and the research questions and objectives. Next, the chapter portrays the significance of the study and its expected contributions. The chapter ends with defining the key terms of the study and organization of the thesis.

1.1 Background of the Study

Over hundreds of years, perusing economic progress leads to major environmental and social problems all around the world. According to Hart (1997), economic growth accompanies by social and environmental challenges such as climate change, pollution, resource depletion, poverty and inequality. In table 1.1 different issues has been summarized that occur as a result of pursuing economic growth on different economic stages.

Table1.1: Major Challenges to Sustainability

	Pollution	Depletion	Poverty
Developed economies	<ul style="list-style-type: none"> - Green house gasses - Use of toxic materials - Contaminated sites 	<ul style="list-style-type: none"> - Scarcity of materials - Insufficient reuse and recycling 	<ul style="list-style-type: none"> - Urban and minority unemployment
Emerging economies	<ul style="list-style-type: none"> - Industrial emissions - Contaminated water - Lack of sewage treatment 	<ul style="list-style-type: none"> - Overexploitation of renewable resources - Overuse of water for irrigation 	<ul style="list-style-type: none"> - Mitigation to cities - Lack of skilled workers - Income inequalities
Survival economies	<ul style="list-style-type: none"> - Dung and wood burning - Lack of sanitation - Ecosystem destruction due to development 	<ul style="list-style-type: none"> - Deforestation - Overgrazing - Soil loss 	<ul style="list-style-type: none"> - Population growth - Low status of women - Dislocation

Source: Hart, (1997)

However, the major sustainability issues related to manufacturing industries are environmental issues. Due to the fact that rapid industrialization which are undertaken for social development and economic growth accompanied by sever negative environmental impact (Zeng, Liu, Tam & Shao, 2008). This can be seen in of the Sustainable Development Strategy in the UK by outlining the objectives of sustainability and emphasis on the importance of environmental challenges in pursuing sustainable development as “The sustainable social progress which recognizes the needs of everyone, effective protection of the environment, prudent use of natural resources and lastly, maintenance of high and stable levels of economic growth and employment” (Paramanathan, Farrukh, Phaal & Probert, 2004).

According to Beamon (1999), “indeed, waste generation and natural resource use, primarily attributed to manufacturing, contribute to environmental degradation.” Incremental economic, environmental and social concerns challenges manufacturing companies to design their products and manufacturing processes in a sustainable way in order to conserve energy, reduce waste, eliminate pollution and creating value for the stakeholders and the communities where the company conducts its business (Hibbard, 2009; Pojasek, 2010). In fact, sustainable manufacturing with integrating triple bottom line of environmental, economic and social perspective is a new essential paradigm for manufacturing companies in confronting sustainability issues facing the world (Herrmann, Thiede, Stehr & Bergmann, 2008). Leahu-Aluas and Burstein (2010) highlighted that sustainable manufacturing uses a wide range of technological and non-technological solutions, from selection of materials and production processes to organizational mission, structure and performance reporting. It shifts the focus from a traditional command and control or “end-of-pipe-line” solutions which includes disposal of

waste, clean-up, and recovery, to a proactive approach which includes the very beginning, at product or process design stage.

This section provides background information about environmental challenges as the main issues for manufacturing industries confronting the world and Malaysia. Further, the chapter provides explanation about a background of sustainable manufacturing. In addition, it proposes lean practices as a potential solution to address these issues.

1.1.1 Global Environmental Issues

Nowadays, the world suffers from various environmental problems at global scale. Eltayeb (2009) commented that many scientists considered global warming and ozone depletion as the most severe environmental problems that threatening the life on earth. Global warming and climate change according to Shah (2010), refers to increase of the average global temperature.

As it is stated by the Intergovernmental Panel on Climate Change (IPCC) report in 2007 “warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level” (O’Day, 2007). Researches indicate that the climate change is caused primarily by emission of greenhouse gases such as Carbon Dioxide (CO₂) as a result of human activities in pursuit of economic development such as fossil fuel burning and deforestation (Logamuthu & Zailani, 2010; Tersine, 2004). This climate trend has been shown in the Figure 1.1 that was prepared by O’Day (2007) for the NASA’s Goddard Institute of Space Studies (GISS) as a part of long term assessment efforts for tracking global temperature climate trend. This figure indicates the global temperature anomalies between 1800 and 2006.

Global Temperature: 1880-2010
land-Ocean index 1951-1980

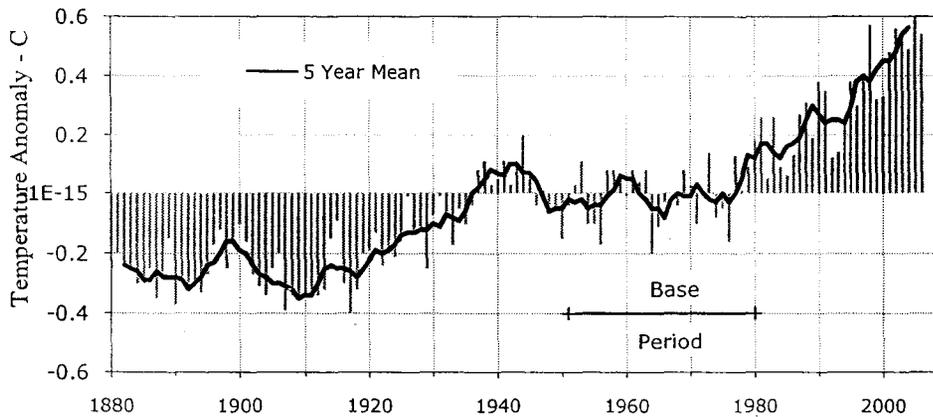


Figure 1.1: Global Temperature: 1880-2006

Source: O'Day (2007) from http://processtrends.com/pg_global_warming.htm

Another important environmental concern is Ozone loss which has been depleting for many years. As it is stated by Suurkula (2004), Ozone depletion is caused by accumulation of green house gases and will increase Ultraviolet radiation. Further, Shah (2002) explained that the Ozone layer shelters living creatures on earth from harmful impacts of the Sun's ray. News indicated that the Ozone hole over Antarctica is three times more than the size of the United States and it is growing. This observation reinforces concerns because it is believed that Ozone depletion is the main cause of high rate of skin cancer (BBC News, 2000).

It must be considered that developing countries especially countries located in South and South East Asia are the most impacted by environmental problems (Eltayeb, 2009). In addition to global environmental problems, countries are suffering from local environmental problem such as water pollution, air pollution and waste disposal.

1.1.2 Environmental Issues in Malaysia

Globalization makes the world more tightly knit and transfers majority of manufacturing to the South-East Asia with cheaper production processes as a production house (Rao, 2004). While industrialization brings considerable economic and social benefits, it can lead to negative environmental impacts (Huong, 1999). Therefore, it is important for Malaysia to achieve a balance between high standard of living and environmental protection. However, the critical issues of focus for Malaysian manufacturers are bottom line and market share while environmental sustainability is not a pressing concern (NIMRC, 2008). So, it is essential to address the environmental issues in this region before it leads to serious environmental trouble. The importance attached to recognition of the debilitating effects of environmental pollution has urged governments, communities and industries of the nations of these regions to take appropriate actions against this problem (Rao, 2004).

Zeng, Liu, Tam and Shao (2008) argued that most of the nations of this region suffer from severe poverty and lack of basic facilities and manufacturing industries considered as the main driving force of social development and economic growth. However, rapid industrialization process is the main cause of many social and environmental problems due to the fact that industrial process was undertaken with little regard to the effect on environment.

During the last five decades Malaysia is experiencing the rapid economic, social and environmental change, a trend that still continues (Hezri & Hasan, 2006). According to Choy (2004), manufacturing industries have expanded tremendously as a result of transforming Malaysia's economy from an agricultural base to industrial orientation. Malaysia's industrialization strategy is based on the "vision 2020" which is a long term plan to become a fully industrialized country on the same level as advanced nation of the world. The aim of

“vision 2020” is to direct the country’s future development toward industrial restructuring, using technological advances, and human resource enhancement (Choy, 2004). As it is mentioned by Eltayeb (2009), according to Malaysian Industrial Development Authority report (2007), Malaysian manufacturing sector contributed 32% of the gross domestic product (GDP) and exports of manufactured products account for 75% of Malaysia’s total export in 2007. While industrialization brings significant economic and social development, it has negative environmental impact such as air pollution, water pollution, land pollution and degradation of natural resources. Therefore, it is essential in Malaysia to achieve a balance between high living standard and environmental protection. Table 1.2 represents a summary of major environmental problem facing Malaysia.

Table 1.2: Major environmental concern in Malaysia that caused by manufacturing sector

Environmental problem	source of problem	Effect:	Sources:
Water pollution	Untreated industrial toxic hazardous wastes such as heavy metals, polyaromatic hydrocarbons (PAH), oil and grease	Interruption in water supply, threaten the health of ecosystems	Hezri and Hasan (2006)
Air pollution	Transportation, solid waste, fuel combustion by stationary sources, industrial processes and open burning, including by neighboring countries	Affect human health	Hezri and Hasan (2006), ESCAP (1999)
Exploitation of natural resources	Development of timber industry, expansion of urban and industrial areas	Mineral resources sterilization, encroachment of existing mines and quarries	Hezri and Hasan (2006), ESCAP (1999)
Land pollution and solid/ hazardous wastes	Growing level of industrialization and consumption has increased the generation and types of solid waste	Affect human health, threaten biodiversity	Eltayeb, (2009)

Based on Table 1.2, environmental problems in Malaysia can be grouped into four major categories: (1) water pollution such as discharge different inorganic compounds, including heavy metals, into open water courses without prior treatment; (2) Air pollution such as haze episodes, particulate matter, and ground level ozone; (3) Exploitation of natural resources such as mineral resources, extensive logging of timber; (4) land pollution which include solid and hazardous wastes such as lead and oil.

A recent environmental quality report published by the Malaysian Department of Environment stated that at 2009 the number of clean river has been decreased compared to 2008. The reduction of clean rivers is related to contaminating sources such as sewage treatment plants, manufacturing industries and palm oil miles (DOE, 2009). The report emphasized that the great portion of this pollution is due to manufacturing activities. Manufacturing industries has been identified to be accountable for 45.07% of total water pollution point source (DOE, 2006) .

Hezri and Hasan (2006) commented that the other environmental concern in recent years is increasing pollution of air as a result of transportation, industrial manufacturing and open burning, which in turn cause considerable concerns over human health impact. In addition, Hassan, Awang and Jafaar (2006) noted that in recent years, increasing the amount of solid wastes as a result of growing the level of industrialization and consumption is another main issue of concern in Malaysia. The most hazardous part of solid wastes is scheduled or unsafe wastes which may directly affect human health. According to environmental quality report in 2006 “a total 548916.11 metric tons of scheduled wastes were generated in 2005 as compared to 469584.07 metric tons in 2004” which indicate the amount of unsafe wastes produced by manufacturing is increasing (DOE, 2006). However, despite the extensive efforts to endorse

reuse reduction and recycling of materials the amount of solid waste recycled remained at less than 5% of total disposed waste (Ninth Malaysia Plan, 2007).

Increasing the consciousness among the people about environmental contamination which was accompanied by socio-economic progress has followed by protest marches and demonstration. Comprehensive array of policy statements and regulation has been formed in order to protect sustainable development. These movements undertake in order to influence the organizations to take proactive steps in protecting the environment, however despite efforts of government to implement sustainable development and growing public awareness of environmental issues, environmental challenges still remain today (Hezri & Hasan, 2006).

Some studies summarized the main reason for remaining environmental challenges in South-East Asia in general and Malaysia as follow:

Piecemeal efforts: for ensuring compliance many firms have adopted polluted control practices such as air emission control, treatment of polluted water and appropriate disposal of toxic wastes. However, these activities were piecemeal due to the fact that they were not integrated into overall company's strategies.

Emphasis on cure more than prevention: most of the adopted solutions were "end-of-the-pipe" solutions where a firm emphasis on pollution control after they are created rather than pollution prevention and adopting a proactive approaches to reduce the pollution at its source.

High cost is deterrent: High cost associated with implementation of environmental regulation affair is a deterrent. In addition to high cost of such measures, lack of technical know-how and the absence of proper equipment act as other deterrent factors.

Difference in prioritization: the level of priority to environmental issues among countries of region is different. The priority level depends on the presence of government policies and public pressure groups, international pressure and NGOs activity.

Weak enforcement: in compare to western countries, enforcement of the regulations has been weak regarding to environmental issues and informal systems provide many loopholes in this region (Anbumozhi & Kanda, 2005; Eltayeb, 2009; Rao, 2004).

The above discussion indicates that Malaysia as well as other countries of South-East Asia are confronting serious challenge regarding how to balance economic development with environmental sustainability and hence, achieving the triple bottom line of sustainability: social, economic and environmental performance (Carter & Rogers, 2008a; Eltayeb, 2009; Weford, 2004; Wells & Seitz, 2005). In response to these challenges, Hibbard (2009) and Pojasek (2010) claimed that business organizations start to design their products and manufacturing processes in a sustainable way in order to conserve energy, reduce waste, eliminate pollution and creating value for the stakeholders and the communities where the company conducts its business.

1.1.3 Background of Sustainable Manufacturing

The term sustainability has been used to include environmental management, supply chain management and a broad perception of triple bottom line thinking into operations, culture and strategy of the companies (Kleindorfer et al., 2005). For a long period of time, economic growth and society equity were the primary concern of societal development process. Environmental concerns began in the late 1960s in the U.S. and rapidly spread across the world afterwards. So, interconnection between environment, economy and social well beings has been realized (Hu, 2009).

In respond to increased environmental concerns as a result of economic growth and global expansion of business and trade, The World Commission of Environment and Development (WCED) in its report in 1987 acknowledged the trend by defining a new term “sustainable development” which has had great impact on political, economic and social sectors. Sustainable development has been defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

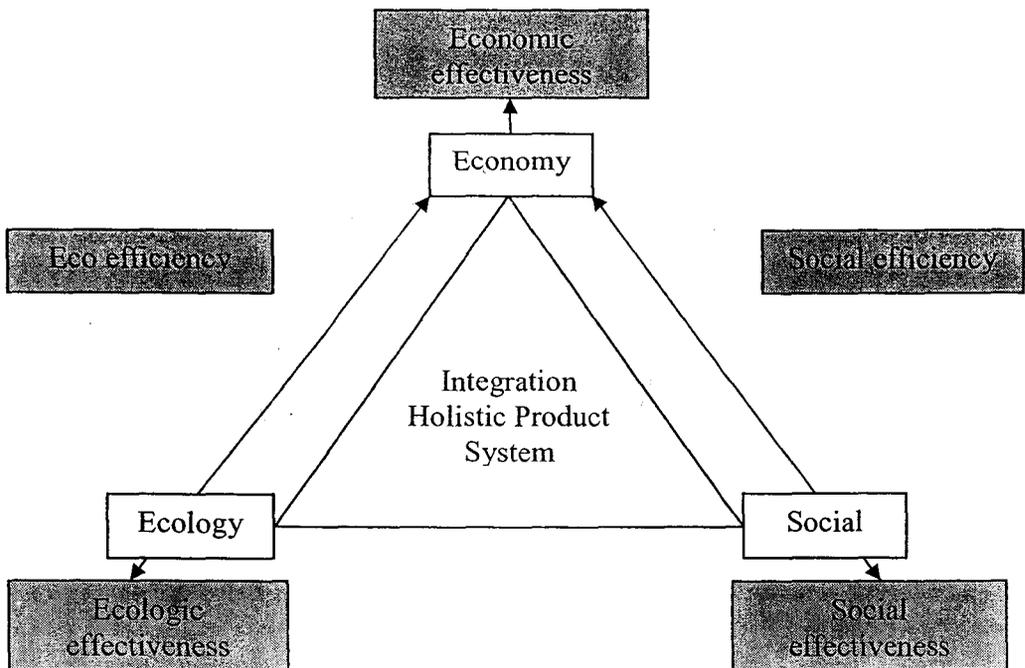
- The concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and
- The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs" (Bruntland, 1987).

U.S. Department of Commerce defined sustainable manufacturing as “the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound” (Trade, 2010). Ever since, as it is claimed by Leahu-Aluas and Burstein (2010) and Pojasek (2010) sustainable development has become expected business practice by small and large companies and guided policy decisions and strategic planning. Even it has been expanded to companies’ networks of suppliers and customers.

The challenge that businesses face today is to keep their operating profitable while conforming to sustainability issues. After a humble beginning in late 1980’s sustainable manufacturing is experiencing major shift in philosophy, acceptance and emphasis toward viewing the sustainable manufacturing as a journey instead of considering a destination or static state (Pojasek, 2010).

Westkamper (2008) explained that there are various definitions and dimensions for sustainability but in the field of manufacturing, sustainability means optimizing the overall efficiency of enterprises, products and processes. In this area, efficiency can be viewed from three aspects of ecology, economy and social perspective. Reducing cost of materials and energy can improve economic effectiveness. Optimizing resource consumption leads to economic and environmental effectiveness. In addition, manufacturing have social dimensions such as workforce skills, education, work conditions and cultural aspect of work that have effect on social effectiveness of the company. Figure 1.2 provides a visual perspective about the definition of sustainability based on optimizing the overall efficiency.

Figure 1.2: Sustainability and Efficiency



Source: Westkämper, (2008)

In order to achieve sustainable manufacturing with its triple bottom line of environmental, social and economic, three criteria of optimization (cost, time, and quality) must be integrated with methodologies such as lean, JIT, TQM and etc (Westkämper, 2008). Jergensen (2008) suggested that lean manufacturing offers great opportunities for performance improvement by practices such as waste elimination, just-in-time production methods and continuous improvement of existing work practices.

Many manufacturing restrict their so called sustainability efforts to environmental aspect of it while for considering a practice to be truly sustainable three dimensions of environmental, social and economic outcomes needed to be examined and those who limit their sustainability effort to one of them do not fit the definition (Pojasek, 2010). Jergensen, Matthiesen, Nielsen and Johansen (2007) noted that sustainability with respect to lean manufacturing means how much lean practices may support reduction of environmental impact with efficient use of raw materials and energy supplies or how lean practices can lead to economic stability to provide future growth for organization. Sustainability in this context means to maintain a balance between resources for today's need while ensuring the protection of resources for future needs.

This study, however, will specifically address the issues of achieving sustainable manufacturing through lean practices. It is believed that a sustainable manufacturing is a promising area of study and practice that have the potential to provide significant benefits to the firm and the society.

1.2 Problem Statement

In order to realize “Vision 2020” Malaysia is experiencing transformation from an agricultural base to industrial orientation (Choy, 2004). However, Economic and social benefits of industrialization usually accompany by negative environmental impact (Eltayeb, 2009). According to Hassan, Awang and Jaafar (2006), “the challenge for the new millennium is to develop an industrial system that has minimal socio-ecological impacts, without compromising quality of life.”

According to Nottingham Innovative Manufacturing Research Center (NIMRC) report (2008), sustainability issues are not generally perceived as critical by manufacturers in Malaysia. However, internal and external legislation pressures are increasing the awareness of sustainability regarding to their business. This can be seen in Malaysia Prime Minister announcement regarding to the outline of proposed New Economic Model. According to his speech at the Invest Malaysia Conference the objective of New Economic Model is “to become a high-income, developed, resilient and competitive nation, in the interest of the well-being of all Malaysians” but not at all cost. The growth process must be both inclusive and sustainable. Inclusive growth is the main prerequisite to ensure the benefits will be shared across all communities. Sustainable growth enhances the wealth of current generation without compromising the ability of future generation to meet their needs. To ensure the sustainability of environment most of the emphasis is on the use of renewable energy and increasing energy efficiency (Tenth Malaysia Plan, 2010).

Most of the strategies have been used to increase efficiency of resources usage are “end of the pipe” solutions such as re-cycling, re-use, re-manufacturing with main efforts on recovery of products or material at the end of their useful life. Less than 20% of all materials used in

manufacturing end up in product and infrastructure. This makes the overall capacity of recycling very limited. So, the main focus should be on production system processes rather than end of the pipe solutions to achieve real efficiency in manufacturing process (Abdul Rashid, Evans & Longhurst, 2008).

There is an assumption that lean approach with main focus on waste elimination has considerable potential for environmental and economic sustainability, and this also comprehend as using less energy, consuming less raw material and generating less toxic waste in manufacturing process (King & Lenox, 2001; Westkämper, 2008; Found, 2009). For example Wallace (1995) suggested that adoptin g continuous improvement in lean provided considerable opportunities for pollution prevention and reducing of waste and emissions. In a similar vein, Kleindorfer et al. (2005) considered lean as a promising area toward sustainable operational management with its triple bottom line. However, the evidence to support this is implicit rather than explicit and casual link is unproven (Found, 2009; King & Lenox, 2001; Moreira, Alves & Sousa, 2010) and in some cases are contradictory (Rothenberg, Pil & Maxwell, 2001; Sarkis, 1995). Therefore, it gave rise to the question that: Does the practices of lean manufacturing more compatible with sustainable manufacturing in compare with traditional mass, or batch, manufacturing?

The existing literature has gap in that it cannot prove cause and effect of lean approach and sustainable manufacturing. Few studies have been conducted in order to explore possible association between lean and potential environmental outcomes (Florida, 1996; Rothenberg et al., 2001). However, the nature of relationship between lean and environmental improvement is not clear (King & Lenox, 2001). Even Zhu and Sarkis (2004) considered lean as double-edge sword that can result to both negative and positive contribution to environment. As it is stated by

Found (2009), until recently the main focus of lean manufacturing was on economic and some social aspect of sustainability. On the other hand, during the past two decades the three components of sustainability have been considered in isolation without taking into account the interdependency between them. So, there is a need for exploring the cause and effect of lean manufacturing on sustainability outcomes with its triple bottom line of environmental, economic and social. Hence, this study focuses on the contribution of lean practices towards sustainable manufacturing with triple bottom line of social, economic and environmental perspectives.

In addition, despite the huge benefit associated with lean implementation in reality many companies are not successful in implementation of lean system (Bhasin & Burcher, 2006; Nordin, Deros & Wahab, 2010; Veech, 2004). Some researchers claim that the lack of lean culture is the main reason that hinders companies to achieve the potential outcome resulting from lean implementation (Bhasin & Burcher, 2006; Höök & Stehn, 2008). Therefore, to finding out the contribution of lean practices toward sustainable manufacturing, the study investigates the moderating effect of lean culture on the relationship between lean practices and sustainable manufacturing.

1.3 Research Objectives

This study is interested to study the contributions of lean practices towards sustainable manufacturing. The specific objectives are as follow:

1. To investigate the contributions of lean practices (process and equipment, manufacturing planning and control, human resource, supplier relationship and customer relationship) to sustainable manufacturing.

2. To examine whether lean culture moderates the relationship between lean practices and sustainable manufacturing.

1.4 Research Question

Based on the research objectives stated above, research questions for this study are as follow:

- 1- What are the relationships between lean practices (Core production function practices, support function practices, extended enterprise practices) and sustainable manufacturing?
- 2- What is the role of lean culture in the relationship between lean principles and sustainable manufacturing?

1.5 Significance of Study

The significance of this study derives from its expected theoretical contributions to knowledge and practical contributions to manufacturing industries as follows:

1.5.1 Theoretical Contributions

Increasing importance of sustainable manufacturing as a result of incremental economic, environmental and social concerns have made manufacturing companies to design their product and manufacturing processes in a sustainable way in order to address related issues (Hibbard, 2009; Pojasek, 2010). So, this research is timely for adding to the knowledge in this important issue. Lean practices with main focus on continuous improvement and elimination of all types of wastes from production processes, engages employees in reducing the lead time, materials and capital necessary for meeting ever increasing customer's demands has potential to contribute to sustainable manufacturing (EPA, 2003).

Lean is one of common methodologies that many companies use in order to cope with business environment challenges whereas main objective of lean implementation is cost reduction and quality improvement which are not necessarily environmentally friendly (Herrmann, Thiede, Stehr & Bergmann, 2008). Some studies have shown that implementation of lean practices improve environmental performance (King & Lenox, 2001; Westkämper, 2008). Although few studies have shown that implementation of lean principles improve environmental aspect of sustainable manufacturing, there is a lack of empirical evidence about the contribution of lean on other aspects of sustainability. While for considering a practice to be truly sustainable three dimensions of environmental, social and economic outcomes needed to be examined (Pojasek, 2010).

Based on extensive literature review, the study believes that no other empirical study that investigates the contribution of lean practices to sustainable manufacturing has been done in Malaysia. In addition no other study has been done in order to investigate the moderating effect of lean culture on this kind of relationship. For that reason, this study is expected to add knowledge to the following areas of sustainable manufacturing:

- 1- The study identifies the influence of lean practices to sustainable manufacturing and reveals the impact level of each lean practice in different areas of company on triple bottom line of sustainability (environmental, economic, social). Giving that knowledge about the existence and level of this impact can add considerable knowledge in this area and provide a base for further studies about the issue. This knowledge can also enrich theories that deal with the concept of sustainability among manufacturing.

- 2- The study investigate the level of existence of lean culture in manufacturing companies in Malaysia and encloses the moderating effect of lean culture on relationships between lean practices and sustainable manufacturing. This can add knowledge about what enables or facilitate the relationship between lean practices and its potential outcomes.

1.5.2 Practical Contributions

It is expected that this study improves the knowledge and performance of managers and generally manufacturing industries in Malaysia.

- 1- The study identifies the extent of implementation of lean practices in different functional areas of companies in Malaysian manufacturing and therefore, can add knowledge about potential areas for improvement. In addition, the study helps to identify pros and cons associated with lean practices in different functional areas which provide information for managers to avoid side effects or disadvantages of lean practices and strengthen the advantages of them.
- 2- The study can reveal the potential outcomes of lean practices regarding to sustainable manufacturing. This can enhance managers' understanding of the importance and value of achieving sustainable manufacturing through production process initiatives particularly lean practices, instead of end of the pipe solutions. This understanding is very critical due to increasing importance over sustainability issues in Malaysia and realizing the objective of New Economic Model.

1.6 Key Terms Definition

Sustainable manufacturing: US Department of Commerce (2009) defined sustainable manufacturing as: "the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound." Sustainable manufacturing address the challenge of keeping the companies operating profitable while considering the environmental and social concerns.

Sustainable development: According to Bruntland Report "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- The concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and
- The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs"(Leahu-Aluas, 2010).

Environmental outcome: Environmental outcomes represent positive consequences of initiatives that is undertaken in order to achieve sustainability such as green supply chain initiatives, green procurement on environmental performance of a firm and include compliance to environmental standards, reductions in air emissions, resource consumption, and consumption of hazardous materials (Eltayeb, 2009; Geyer & Jackson, 2004; Zhu & Sarkis, 2004).

Economic Outcome: Economic outcomes represent actual impacts of initiatives that is undertaken in order to achieve sustainability on financial performance of the firm such as increase in market share, profitability and productivity improvement and revenue growth, reducing production cost (Eltayeb, 2009; Rao & Holt, 2005; Zhu & Sarkis, 2004; Zhu, Sarkis & Lai, 2007).

Social Outcome: conceptual or difficult to quantify outcomes such as enhanced product image and improved goodwill and image of a company from perspective of its stakeholders (Govindasamy, 2010).

Lean Manufacturing: lean has been defined by the National Institute of Science and Technology (NIST) Manufacturing Extension Partnership (MEP)(1998) as "... a systematic approach to identifying and eliminating waste (non-value-added activities) through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection" (Buzby, Gerstenfeld, Voss & Zeng, 2002).

Lean Practices: comprise of practices that is vital for successful implementation of lean. Some of the most common practice of lean include: Kanban, value stream mapping, 5S, cellular manufacturing, mistake proofing, reduced cycle time and so on (Worley, 2004).

Process and Equipment: Practices related to process and equipment area comprise of practices that aim to make sure the availability of production processes and optimized equipment that are able to guarantee the regularity and uniformity, over time (Panizzolo, 1998).

Manufacturing Planning and Control: include a bundle of practices such as the use of small lot size, pull control and visual control of shop floor and so on with the main purpose of synchronizing production and market demand (Panizzolo, 1998).

Human Resource: the human element of lean manufacturing which focuses on development of human capital to support lean objectives through creating proper work environment. This include employee's involvement, empowerment, formal training programs, problem solving groups, self-directed work teams and autonomous problem solving. According to Bergmiller (2006), human resource management practices refer to company-wide policies that govern the relationship between management and employees.

Supplier Relationship: The degree of interaction with the supplier regarding quality concerns in terms of long-term relationships, number of suppliers, providing regular feedback to suppliers about their performance, ensuring JIT delivery by the suppliers, supplier involvement in product design and development processes (Ahmad, Schroeder & Sinha, 2003; Doolen & Hacker, 2005; Panizzolo, 1998; Shah & Ward, 2007).

Customer Relationship: The way in which company interact and deals with its customer in order to manage customers complains, enhance customer satisfaction and building long term relationship with customers. The purpose of customer relationship practices are identifying value demanded by customers via establishing a close contact with customer, exchange of information, involving customer in product design and so on in order to sustain customer loyalty, differentiate

its product from competitors and dramatically strive to add more value to its customer (Li, Rao, Ragu-Nathan & Ragu-Nathan, 2005).

Lean Culture: According to Mann (2005) culture of an organization is what is experienced there as a result of its management system. When a company decides to shift paradigms from traditional management to Lean management, the culture of the company undergo fundamental change in values, priorities, norms of behavior and employees attitude.

1.7 Organization of the Thesis

This thesis has been organized in five chapters including current chapter as introduction. Second chapter covers literature review of variables related to this research. Chapter three includes methodology, research procedures and analytical framework that illustrate the development of survey instrument and data collection. Chapter four presents results of analysis and interpretation. This chapter consists of tables with the entire data obtained showing finding on each question. The thesis ends with chapter five which presents summary as part of discussion on the results. The findings of the research are discussed in context of its theoretical and managerial implications, limitation of the study, suggestion for future research and conclusion.