Faculty of Manufacturing Engineering

DEVELOPMENT OF LEAN MANUFACTURING IMPLEMENTATION FRAMEWORK IN MACHINERY AND EQUIPMENT OF SMALL AND MEDIUM ENTERPRISES

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DEVELOPMENT OF LEAN MANUFACTURING IMPLEMENTATION FRAMEWORK IN MACHINERY AND EQUIPMENT OF SMALL AND MEDIUM ENTERPRISES

CHONG JIA YUIK

**A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled "Development of Lean Manufacturing Implementation Framework in Machinery and Equipment of Small and Medium Enterprises" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Chong Jia Yuik..........

Date : 08-Feb-2021.................

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 Master of Science in Manufacturing Engineering.

Signature : ……………………………….

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Date : …11 March 2021………………

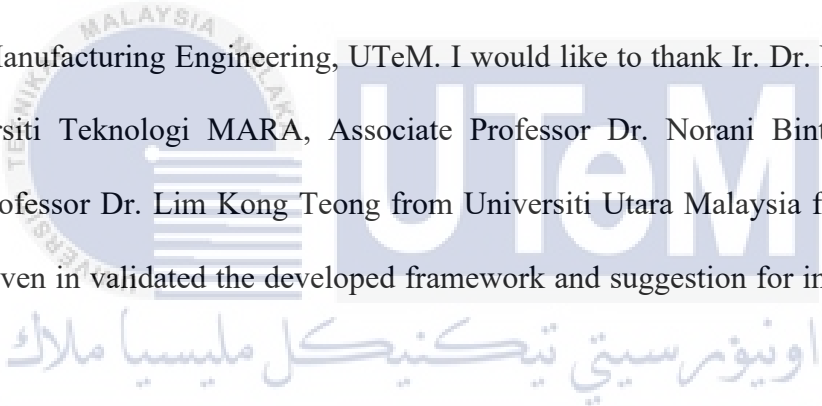**DEDICATION**

To my beloved wife and parents

ABSTRACT

Small and Medium Enterprises (SMEs) form the economic backbone of a country. Similarly, lean manufacturing (LM) has been proven as one of the useful methodologies used in creating value-add to customers and eliminating unnecessary waste. However, the adoption of LM in SMEs is not as vigorous compared to large-scaled organisations. A variety of LM implementation frameworks have been developed in different industries worldwide, but they still lack attention to suit the needs of SMEs. As such, this phenomenon should be investigated more contextually and specifically in an industry cluster. The primary objective of this study is to develop an effective LM implementation framework, which serves as a practical guideline, specifically for machinery and equipment (M&E) SMEs. The present extent of LM implementation in M&E SMEs and critical success factors (CSFs) is presented in this study which employed a mixed-method approach incorporating qualitative research as the main approach supported by quantitative research. Open-ended questions were used in conducting semi-structured interviews with selected multiple case studies involving SME respondents from the different management level. The thematic analysis method was utilised to analyse the qualitative data. Additionally, closed-ended survey questionnaires were employed for the descriptive and statistical data analysis to confirm and validate the results. The findings suggest that the current extent of LM understanding and implementation remains low to moderate, and the success achieved has been imbalanced. The most common challenges faced were related to human resource management (HRM) issues and the employee's level of understanding in adopting lean. The identified predominant CSFs revealed through the analysis and interviews with respondents showed that the importance leading to the success of LM implementation include commitment and leadership of senior-top management, employee training to upgrade skills and expertise, employee involvement and empowerment, and the establishment and implementation of a practical LM framework for SMEs. Aside from that, SMEs revealed that the essence of customer focus could not be ignored. The lean model and strategic LM implementation framework were developed based on a systematic literature review and derived from the practical lean experiences of the three case companies. The conceptual lean model presents a simple and easy to understand structure for M&E SMEs to have an overview of LM implementation in the organisations for strategic planning. The proposed framework consisted of four implementation stages and 22 essential components to cater to the characteristics and features of SMEs. This validated LM framework has covered most of the necessary essential elements, understandable and can be implementable in M&E SMEs for industrial application. The Plan-Do-Check-Act (PDCA) Cycle served as a step-by-step practical approach and offered operational guidance aligned with company management systems. This comprehensive framework would help to ease the effort of SMEs lean practitioners in starting their lean implementation and transformation journey systematically and improve the organisation's performances towards achieving a high degree of success.

PEMBANGUNAN KERANGKA PELAKSANAAN PEMBUATAN KEJAT DALAM MESIN DAN PERALATAN PERUSAHAAN KECIL DAN SEDERHANA

ABSTRAK

Perusahaan Kecil dan Sederhana (PKS) membentuk tulang belakang ekonomi sesebuah negara. Begitu juga, Pembuatan Kejat (PK) telah terbukti sebagai salah satu metodologi berguna yang digunakan dalam mewujudkan nilai tambah kepada pelanggan dan menghapuskan pembaziran yang tidak diperlukan. Namun, penerapan PK di PKS tidak begitu kuat dibandingkan dengan organisasi yang berskala besar. Berbagai kerangka pelaksanaan PK telah dikembangkan di berbagai industri di seluruh dunia, tetapi masih kurang mendapat perhatian untuk memenuhi keperluan PKS. Oleh yang demikian, fenomena ini harus diselidiki secara lebih kontekstual dan khusus dalam kelompok industri. Objektif utama kajian ini adalah untuk mengembangkan kerangka pelaksanaan PK yang efektif dan berfungsi sebagai garis panduan praktikal, khusus untuk mesin dan peralatan (M&P) di PKS. Tahap pelaksanaan PK di PKS M&P dan faktor kritikal kejayaan (FKK) dipersembahkan dalam kajian ini yang menggunakan pendekatan kaedah campuran yang menggabungkan penyelidikan kualitatif sebagai pendekatan utama yang disokong oleh penyelidikan kuantitatif. Soalan terbuka digunakan dalam menjalankan temu ramah separa berstruktur dengan beberapa kajian kes terpilih yang melibatkan responden PKS dari peringkat pengurusan yang berbeza. Kaedah analisis tematik digunakan untuk menganalisis data kualitatif. Selain itu, soal selidik tinjauan tertutup digunakan untuk analisis data deskriptif dan statistik untuk mengenal pasti dan mengesahkan hasilan. Hasil kajian menunjukkan bahawa tahap keseluruhan kefahaman dan pelaksanaan PK tetap rendah-sederhana, dan kejayaan yang dicapai tidak seimbang. Cabaran yang paling biasa dihadapi adalah berkaitan dengan isu pengurusan sumber manusia dan tahap kefahaman pekerja dalam menerapkan PK. FKK dominan yang dikenal pasti telah didedahkan melalui analisis dan wawancara dengan responden menunjukkan bahawa kepentingan yang membawa kepada kejayaan pelaksanaan PK merangkumi komitmen dan kepemimpinan pengurusan atasan, latihan pekerja untuk meningkatkan kemahiran dan kepakaran, penglibatan dan pemberdayaan pekerja, dan penubuhan dan pelaksanaan rangka kerja PK praktikal untuk PKS. Selain itu, PKS mendedahkan bahawa intipati dari fokus pelanggan juga tidak dapat diabaikan. Model kejat dan pelaksanaan PK yang strategik dikembangkan berdasarkan tinjauan literatur yang sistematik dan berasal dari pengalaman praktis dari tiga kes syarikat tersebut. Model kejat konseptual menyajikan struktur ringkas dan mudah difahami bagi PKS M&P supaya mempunyai gambaran keseluruhan tentang pelaksanaan PK dalam organisasi untuk perancangan strategik. Kerangka kerja yang dicadangkan terdiri daripada empat tahap pelaksanaan dan 22 komponen penting untuk memenuhi ciri-ciri PKS. Rangka kerja PK yang disahkan ini telah merangkumi sebahagian besar elemen penting yang diperlukan, mudah difahami dan dapat dilaksanakan di PKS M&P untuk aplikasi industri. Kitaran Plan-Do-Check-Act (PDCA) berfungsi sebagai pendekatan praktikal langkah demi langkah dan menawarkan panduan operasi yang selaras dengan sistem pengurusan syarikat. Kerangka kerja yang komprehensif ini akan membantu meringankan usaha para pengamal PK di PKS dalam memulakan perjalanan pelaksanaan dan transformasi mereka secara sistematik dan meningkatkan prestasi organisasi untuk mencapai tahap kejayaan yang tinggi.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

AHP   -   Analytic Hierarchy Process

CSFs   -   Critical success factors

DOSM   -   Department of Statistic, Malaysia

Eureka   -   Eureka Resources Sdn. Bhd.

FFA   -   Force field analysis

FKK   -   Faktor Kritikal Kejayaan

FMEA   -   Failure Mode and Effects Analysis

FMM   -   Federation of Malaysian Manufacturers

GDP   -   Gross Domestic Product

GM   -   General Manager

HRDF   -   Human Resources Development Fund

HRM   -   Human resource management

ICT   -   Information and Communication Technology

IR4   -   Industrial Revolution 4

ISO   -   International Organization for Standardization

JIT   -   Just-in-Time

KPIs   -   Key performance indicators

LEBM   -   Lean-Excellence Business Management

LM   -   Lean Manufacturing

LPS   -   Lean Production System

M&E	-	Machinery and Equipment
M&P	-	Mesin dan peralatan
MBNQA	-	Malcolm Baldrige National Quality Award
MD	-	Managing Director
MFI	-	Metalfinishing Industries Sdn. Bhd.
MIDA	-	Malaysian Investment Development Authority
MNCs	-	Multinational Corporations
Nadcap	-	National Aerospace and Defense Contractors Accreditation Program
OPL	-	One-Point Lesson
PDCA	-	Plan-Do-Check-Act
PKS	-	Perusahaan Kecil dan Sederhana
PK	-	Pembuatan Kejat
QC	-	Quality control
QMR	-	Quality Management Representative
QMS	-	Quality Management System
RFID	-	Radio frequency identification
ROI	-	Return of Investment
SIPOC	-	Suppliers, Inputs, Process, Outputs, and Customers
SLIM	-	Sustainable Lean Iceberg Model
SMART	-	Specific, Measurable, Attainable, Relevant, and Time-Bound
SMEs	-	Small and Medium Enterprises
SMED	-	Single Minute Exchange of Die
SOP	-	Standard Operating Procedures
SPC	-	Statistical Process Control

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STH	-	STH Wire Industry (M) Sdn. Bhd.
TOE	-	Technology-Organisation-Environment
TPM	-	Total Productive Maintenance
TPS	-	Toyota Production System
UK	-	United Kingdom
US	-	United States
VSM	-	Value Stream Mapping
WI	-	Work Instructions
5W1H	-	Who, What, Where, When, Why, and How

LIST OF PUBLICATIONS

Yuik, Ch. J., Perumal, P. A., and Feng, Ch. J., 2020. Exploring Critical Success Factors for the Implementation of Lean Manufacturing in Machinery and Equipment SMEs. *Engineering Management in Production and Services*, 12 (4), pp.77-91.

Jia Yuik, C., and Puvanasvaran, P., 2020. Development of Lean Manufacturing Implementation Framework in Machinery and Equipment SMEs. *International Journal of Industrial Engineering and Management*, 11 (3), pp.157-169.

Chong, J. Y., and Perumal, P. A., 2019. Conceptual Framework for Lean Manufacturing Implementation in SMEs with PDCA Approach. In: Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, *Symposium on Intelligent Manufacturing and Mechatronics*. pp. 410-418. Melaka, Malaysia, 8 July 2019. Springer, Singapore.

CHAPTER 1

INTRODUCTION

1.1   Introduction

Companies are continually searching for sound methods that are practical to improve productivity and reduce overall operating costs. However, there are many global competitive challenges encountered by manufacturing industries nowadays, especially for Small and Medium Enterprises (SMEs) and therefore, SMEs in particular, must determine the best way to move forward to survive in competitive markets progressively. Lean Manufacturing (LM) is one of the predominant philosophies or methodologies that is relatively easy to adapt and suitable to apply in most organisations (Womack et al., 1990). The benefits afforded to the implementation of lean principles in manufacturing companies include waste elimination and efficiency improvement (Achanga et al., 2006; Andrés-López et al., 2015). Also, LM has been widely recognised as the Toyota Production System (TPS) originating from Japan which has been adopted by many companies worldwide since 1960 (Ohno, 1988). Indeed, LM also applies to different industries regardless of their size (Womack et al., 1990).

In 2016, the number of SMEs in Malaysia were 907,065 or 98.5% of total business establishments in the country, contributing around 36.6% of the nation's GDP, 65.3% of employment and 18.6% of exports. The size of SMEs varies but mainly in 2016, consisted of microenterprises, or 76.5% (having less than five employees), and were mainly concentrated in the services sector (89.2%), manufacturing (5.3%), construction (4.3%), agriculture (1.1%), and mining and quarrying (0.1%) as shown in Figure 1.1.

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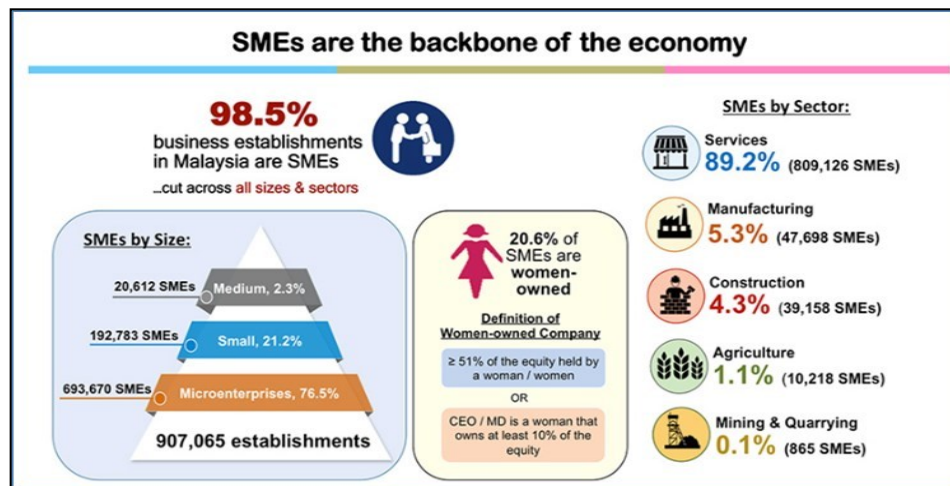
Figure 1.1: SMEs by sector and size in Malaysia (DOSM, 2017)

In 2017, the contribution of SMEs in Malaysia with respect to the nation's GDP increased from 37.8% or RM491.6 billion to 38.3% or RM521.7 billion in 2018 (Department of Statistic, Malaysia (DOSM), 2019). The M&E industry plays a strategic role in the economy of Malaysia with cross-sector connections across all business segments. However, as technological developments in the industry are progressing at a steady pace, Malaysian business leaders have both challenges and opportunities to create new businesses. As such, the M&E SME sector plays a key role in the development of the manufacturing sector in Malaysia. This is aligned with the 11th Malaysia Program, as M&E is viewed as a catalyst for the transition to greater prosperity in the country's economy (Malaysian Investment Development Authority (MIDA), 2019). Also, M&E sector exports in 2018 achieved total RM40.5 billion (US$10.3 billion), as shown in Figure 1.2. This figure is expected to grow at an average annual growth rate of 4.1% to reach RM43 billion (US$10 billion) by 2020. Likewise, in year 2000 imports increased from RM31.9 billion (US$10.6 billion) to RM73.7 billion (US$18.8 billion) in 2018, as shown in Figure 1.3. This indicates that Malaysia's rapidly growing economy in the M&E sector and market stimulates the country's economic growth and transformation of the economy to a great extent.

Sub-Sectors	2013	2014	2015	2016	2017	2018	Major Destinations
	RM bil (US$ bil.)	RM bil (US$ bil.)**	RM bil (US$ bil.)**	RM bil (US$ bil.)'	RM bil (US$ bil.)"	RM bil (US$ bil.)"'	
Power Generating M&E	2.0 (0.7)	2.3 (0.7)	2.6 (0.7)	2.6 (0.6)	3.4 (0.8)	3.3 (0.8)	Singapore, USA, Japan, Germany, UK
M&E for Specific Industries	9.8 (3.3)	10.7 (3.1)	14.5 (4.1)	15.2 (3.5)	16.2 (2.6)	16.1 (3.8)	Singapore, USA, Japan, Indonesia, Thailand
Metalworking M&E	1.3 (0.4)	1.7 (0.5)	1.6 (0.5)	1.5 (0.3)	2.0 (0.5)	1.9 (0.4)	Singapore, Hong Kong, Japan, USA
General Industrial M&E, Components and Parts	14.2 (4.7)	15.3 (4.4)	17.6 (5.0)	18.4 (4.3)	18.6 (4.1)	19.2 (4.6)	Singapore, Hong Kong, Japan, USA, Australia
TOTAL	27.3 (9.1)	30.0 (9.1)	38.3 (10.4)	37.7 (8.4)	40.2 (10.3)	40.5 (9.6)	

Figure 1.2: Export for different M&E sub-sectors (MIDA, 2019)

Sub-Sectors	2013	2014	2015	2016	2017	2018	Major Destinations
	RM bil (US$ bil.)	RM bil (US$ bil.)**	RM bil (US$ bil.)**	RM bil (US$ bil.)'	RM bil (US$ bil.)"	RM bil (US$ bil.)"'	
Power Generating M&E	10.9 (3.6)	11.0 (3.6)	11.7 (3.3)	14.3 (3.3)	15.1 (3.9)	15.0 (3.6)	USA, Japan, Singapore, China, Thailand
M&E for Specific Industries	16.3 (3.6)	16.3 (3.6)	17.2 (3.3)	17.3 (3.3)	25.1 (6.4)	23.9 (5.7)	Japan, Germany, USA, Taiwan, Singapore
Metalworking M&E	4.2 (3.6)	4.2 (3.1)	3.9 (3.3)	3.6 (3.3)	4.6 (1.2)	4.7 (1.1)	Japan, Germany, USA, Taiwan, Singapore
General Industrial M&E, Components and Parts	23.1 (3.6)	23.1 (3.1)	26.7 (3.3)	29.9 (3.3)	33.7 (8.6)	30.1 (7.1)	Japan, USA, Germany, Singapore, Taiwan
TOTAL	54.5 (18.1)	54.8 (15.6)	59.5 (17.0)	115.1 (15.1)	78.5 (20)	73.7 (17.5)	

US$ 1 = RM3 **US$1 = RM3.5 'US$1 = RM4.3 "US$1 = RM3.9 "'US$1 = RM4.2

Figure 1.3: Import for different M&E sub-sectors (MIDA, 2019)

Furthermore, SMEs indicated that their firms achieved LM from 1 to 5 years, even though there were some challenges in SMEs to implement LM (Rose et al., 2013b). The majority of the survey respondents have high perceptions of the importance of LM practices. However, it was determined from the survey that the degree of actual LM implementation and practice is still low (Rose et al., 2013a). Bakar et al. (2017) studied lean management practices in the local government services sectors, specifically city councils, which is essential for quality enhancement in the public sector in Malaysia. Khusaini et al. (2014) showed that LM is at its infancy level in the food and beverage industry in Malaysia. The

application of LM is less common in the Malaysian wood and furniture industry, because of the lack of knowledge-related issues, and the challenges during lean transformation (Abu et al., 2019).

More recently, the application of LM in various types and forms of industries has grown tremendously and is now widely recognised that organisations that have adopted and applied LM methods have realised cost and quality advantages compared to traditional organisations that have not changed their practices (Pavnaskar et al., 2003). However, many SMEs continue to fail in their endeavours and initiatives in adopting lean and faced many challenges throughout their LM implementation journey due to various reasons (Matt and Rauch, 2013). As such, many SMEs have been left behind and have not adopted the notion of adopting LM in their organisation (Achanga et al., 2006). In Malaysia, Machinery and Equipment (M&E) manufacturing is classified into four major sub-sectors (MIDA, 2019):

- Specialised process machinery or equipment for a specific industry;

- Metalworking machinery;

- Power generating M&E; and

- General industrial M&E, components, and parts.

The M&E sector is one of the critical manufacturing industries globally, failing to take advantage of LM implementation and using a proper approach. Indeed, it is important to adopt an appropriate LM implementation methodology for M&E SMEs to take advantage of LM and organisational transformation to sustain the business, profitability, and growth.

1.2 Problem statement

In this competitive economic environment, SMEs globally continue to seek opportunities for continuous growth and improvement in their respective markets. Importantly, SMEs play an essential role in contributing to the manufacturing industry and

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the economy and continually strive to cope with the many challenges facing them in remaining competitive with other organisations, especially in this Industrial Revolution 4 (IR4) era. Malaysia's SMEs Gross Domestic Product (GDP) achieved a numerous growth at 6.2% exceeded Malaysia's GDP which recorded at 4.7% in 2018. One of the systematic manufacturing approaches that can be utilised by M&E SMEs to increase production efficiency and create value-add to customers is via the LM implementation. Manufacturing companies that have implemented LM are able to enjoy many benefits such as increasing profit margins and expanding their business and market growth. In other words, SMEs are the backbone of the economy, in which 98.5% of business establishments in Malaysia are SMEs (DOSM, 2017).

However, many studies have shown that LM's actual implementation in SMEs remains on the low side. For instance, Rose et al. (2013b) conducted a survey of 30 automotive component manufacturing firms indicating that the extent of lean in Malaysia remains low. LM tends to be mostly applied in manufacturing and service industries, such as the automotive industry, although the successful implementation in the M&E industry is poor. This situation is understandable since LM has a long history with the TPS originating from Japan, which is oriented towards the automotive industry. Although, other industries such as M&E continue to face many challenges due to the low maturity of lean, and limited research that has focused on the application of LM in the M&E sector.

Nevertheless, there remain some weaknesses and barriers in LM implementation due to several factors such as the lack of a suitable LM framework, specifically designed for SMEs to follow resulting in LM initiatives to fail (Belhadi et al., 2016). Also, the majority of LM frameworks are developed for large manufacturing companies, and for SMEs (Almanei et al., 2017), even though there is no previous framework cited for lean implementation in SMEs, regarding its failure in this context (Alkhoraif et al., 2019). The

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most common problem in implementing lean concepts for SMEs is due to the lack of understanding of the concept and its principles (Ulewicz and Kucęba, 2016). Although many enterprises succeed in applying LM worldwide, less than 20 percent have achieved and maintained lean activities for an extended period (Minh and Ha, 2016). This suggests that SMEs still need to determine the best approach to implement LM. Nevertheless, there are various types of LM implementation frameworks proposed by researchers and academicians to apply in different sectors and industries. However, these frameworks are predominantly focused on large-scaled organisations. Given the lack of a suitable implementable framework to apply in the M&E SME environment, and it has restricted the ability of SMEs to enjoy similar benefits as other large organisations. Therefore, for these reasons, this study aimed to investigate the current extent of LM implementation in M&E SMEs and to develop a systematic LM model and framework incorporating critical success elements in addressing the limitation of existing frameworks. However, it is beneficial for the management of SMEs and lean practitioners to understand their present position in adopting LM and employ the proper approach to begin their lean journey effectively for continuous improvement and to achieve the success result in organisational performances.

1.3   Research questions

The research questions developed for this study in meeting its aims and objectives include:

i.   What is the perception of M&E SME employees towards the level of understanding, the extent of application for LM implementation and the success level?

ii. Is there are significant difference for selected predominant critical success factors (CSFs) on the importance of LM implementation in M&E SMEs?

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