DEVELOPMENT OF INTEGRATED LEAN SIX SIGMA MODEL FOR SMALL AND MEDIUM ENTERPRISE

by

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LIST OF ABBREVIATIONS

BOM	Bill of materials
BPR	Business process reengineering
CED	Cause and effect diagram
DMAIC	Define, Measure, Analyze, Improve, Control
DOE	Design of experiment
DPMO	Defects per million of opportunities
FIFO	First in, first out
FMEA	Failure mode and effect analysis
GDP	Gross domestic product
GR & R	Gage repeatability and reproducibility
GT	Group technology
ILSSD	Integrated Lean and Six Sigma tools in DMAIC
IT	Information Technology
ISO	International organization for standardization
JIT	Just in time
LSS	Lean Six Sigma
MRP	Material resource planning
NVA	Non-value added
OEM	Original equipment manufacturer
PCB	Printed circuit board
PFA	Production flow analysis
QCD	Quality, cost and delivery
QFD	Quality function deployment

SD	Standard deviation
SIPOC	Supplier-input-process-output-customer
SME	Small and medium enterprise
SMED	Single minute exchange die
SOP	Standard operating procedure
SPC	Statistical process control
TPM	Total productive maintenance
TQC	Total Quality Control
TQM	Total Quality Management
VA	Value added
VOC	Voice of customer
VSM	Value Stream Map
WIP	Work in process

LIST OF SYMBOLS

C	Customer demand
P	Product characteristic
p_j	Part mix fraction of part j
Q	Quality
R_p	Production rate
t	Processing time
T_w	Waiting time
WL_i	Workload of a station i
WL_{n+1}	Workload of part handling

PEMBANGUNAN MODEL BERSEPADU *LEAN SIX SIGMA* UNTUK PERUSAHAAN KECIL DAN SEDERHANA

ABSTRAK

Sistem pengurusan telah dibangunkan untuk membimbing pengilang untuk penambahbaikan berterusan dalam aspek kualiti, kos dan penghantaran. Pembangunan sistem pengurusan yang terkini, *Lean Six Sigma (LSS)* ialah integrasi di antara *Lean Manufacturing* dan *Six Sigma*. Pelbagai model *LSS* telah dibangunkan dan dilaksanakan dalam pelbagai industri dengan bukti yang positif dan kukuh. Walau bagaimanapun, literatur dalam pembangunan dan pelaksanaan model *LSS* di Perusahaan Kecil dan Sederhana (*SME*) adalah terhad disebabkan oleh kekangan saiz pengurusan dan sumber. Kajian ini membangun model *LSS* yang bernama Model Persepaduan alat *Lean* dan *Six Sigma* dalam *DMAIC* (*ILSSD*) yang mengambil kira kekangan ini dalam pemilihan teknik dan alat untuk penambahbaikan berterusan. Model ini memperoleh matlamat pernambahbaikan berterusan daripada misi dan visi sesebuah syarikat. Model *ILSSD* terdiri daripada metodologi *DMAIC* dan mencadangkan kolaborasi penggunaan alat-alat *Lean* dan *Six Sigma* yang tidak memerlukan analisis statistik yang mendalam, misalnya, *Value Stream Map (VSM)*, analisis Pareto, rajah sebab dan akibat, rajah perhubungan dan rajah pokok. Pelbagai teknik pengumpulan data juga diperkenalkan. Struktur model *ILSSD* adalah berpacuan data supaya ia memberi sistem sokongan keputusan dengan analisis yang wajar. Kegunaan *ILSSD* telah disahkan di sebuah syarikat *SME* pencetakan label dan sebuah syarikat *SME* semikonduktor di Pulau Pinang. Keputusan pelaksanaan adalah pengurangan masa persediaan sebanyak 18.42% di syarikat pencetakan label dan pengurangan masa tunggu sebanyak 92.8% di syarikat semikonduktor. Kajian ini telah mencapai objektifnya.

DEVELOPMENT OF INTEGRATED LEAN SIX SIGMA MODEL FOR SMALL AND MEDIUM ENTERPRISE

ABSTRACT

Management systems have been developed to guide manufacturers to continuously improve performance in the aspects of quality, cost and delivery. The latest developed management system, Lean Six Sigma (LSS) is an integration of Lean Manufacturing and Six Sigma. Various LSS models have been developed and implemented in different industries with positive and strong evidences. However, literature on developing and implementing LSS models in Small and Medium Enterprise (SME) is scant due to size-related management and resource constraints. This research develop a LSS model named Integrated Lean and Six Sigma tools in DMAIC (ILSSD) model to take into consideration these constraints in the selection of techniques and tools for continuous improvement. The model derives continuous improvement goals from a company's mission and vision. The ILSSD model consist of DMAIC methodology and proposed collaborated usage of Lean and Six Sigma tools which is not heavy in statistical analysis namely Value Stream Map, Pareto Analysis, Cause and Effect Diagram, Interrelationship Diagram and Tree Diagram. Various data collection techniques were also introduced. The ILSSD model was structured to be data driven so that it provides a decision support system with sound analysis. The practicality of ILSSD was validated in an SME label printing company and SME semiconductor company in Penang. The results of implementation are 18.42% reduction in setup time in label printing company and 92.8% reduction in waiting time in semiconductor company. The research has achieved its objectives.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter, consisting of four sections, introduces the development of a management system model based on the principles of Lean Manufacturing and Six Sigma to improve performance such as quality, cost and delivery in Small and Medium Enterprise (SME) manufacturing industries. The first section provides the background of management systems in this research field. The second section highlights contemporary issues related to management systems to support the problem statement in the present study. The third section presents the research aims and objectives and the fourth section presents the scope of study. The final section is an outline of the whole thesis.

1.1 Research background

Manufacturers recognize the need to improve performances to meet customer demands in connection to product quality, cost and delivery (QCD) (George, 2002). A quality product has to fulfil customer expectations and the requirements including serving the utility. A case in point is a car manufacturer's duty includes the securance of its product to safely transport passengers and goods within specific load and without breakdown. In addition to timely delivery of their products, product cost should be kept at a level for reaching an acceptable gain when the product is sold. It is a common knowledge that customer expectation on product quality, cost and delivery is bound to the fundamental law of competition and evolving market.

Manufacturers therefore have to constantly improve to maintain competitive edges over their competitors.

For this reason, several management systems such as Total Quality Control (TQC), Total Quality Management (TQM), Deming's system of profound knowledge, business process reengineering (BPR), Lean Manufacturing and Six Sigma have been developed and implemented (Chiarini, 2011). Of these systems, Lean Manufacturing and Six Sigma have prevailed in recent years (Tan et al., 2012). Large companies such as Toyota, Danaher Corporation, General Electric, Motorola and Honeywell have been in the forefront to implement Lean Manufacturing and Six Sigma, with significant attributable production improvements reported (Kumar et al., 2006).

Six Sigma follows a structured methodology led by improvement specialists to lessen process variation (Schroeder et al., 2008), ultimately to achieve the goal of 3.4 defects per million opportunities (Linderman et al., 2003). This results in a very well controlled and stable process which will be continuously and rigorously monitored. On the other hand, Lean Manufacturing is an all embracing management philosophy to streamline process with a human system to continuously remove wastes in the value chain (Wong et al., 2009). Lean Manufacturing relies on various tools to remove what is generally regarded as the seven Lean wastes of defects, over-processing, travelling, waiting, inventory, motion and over-production (Ohno, 1988). The direct implications are increasing flow of work-in-process (WIP) throughout the production and on-time delivery.

In many cases, implementing either Lean Manufacturing or Six Sigma is deemed inadequate to address and resolve problems and issues (Corbett, 2011). In reference to this, in 1996, General Electric (GE) CEO Jack Welch heralded Six

Sigma as the most important initiative taken by GE and yet, he drew concern on the consistency in product lead time (George, 2002). Implementing Lean Manufacturing and Six Sigma separately gives varied outcomes as efforts by individual systems are often disjointed.

Therefore, many recent studies have integrated both methods which is coined with a new term called Lean Six Sigma (LSS) (Salah et al., 2010; Cheng and Chang, 2012; Vinodh et al., 2014; Swarnakar and Vinodh, 2016). The integration involves Six Sigma methodology and statistical tools as well as Lean Manufacturing tools and techniques. LSS aims to increase process performances resulting in enhanced customer satisfaction and improved bottom line results (Snee, 2010). This is important not only for large companies but also small and medium enterprises (SMEs). An SME is defined by its sales turnover or number of full-time employees. According to SME Corporation Malaysia (2013), in the manufacturing sector, a Medium enterprise has a sales turnover of RM15 mil-RM50 mil or 75-200 employees while a Small enterprise has a sales turnover of RM300,000-RM15 mil or 5-75 employees. In the services and other sectors, a Medium enterprise has a sales turnover of RM3 mil-RM20 mil or 30-75 employees while a Small enterprise has a turnover of RM300, 000-RM3 mil or 5-30 employees.

From the 1900s onwards, the latest trend seems to be downsizing large firms and outsourcing business to SMEs (Lande et al., 2016). According to the statistics reported by SME Corporation Malaysia (2011), SMEs account for 97.3% of total business establishments in Malaysia for the year 2010 and since then have achieved a Gross Domestic Product (GDP) growth of 6.7% in 2015. The Department of Statistics Malaysia (2014) reported that the contribution of SMEs GDP to the country's economy expanded to 33.1% in 2013. The reported figure confirms that the

SME manufacturing industry is growing in size and economic contribution. Therefore the adoption of management practices by SME is an 'important determinant of success in the global market place' (Kumar et al., 2014, p. 6482).

1.2 Problem statement

Various methods are conceived to integrate Lean Manufacturing and Six Sigma based on contextual issues faced by manufacturers (Antony et al., 2003). For example, when manufacturers are faced with an issue to identify process variables that affect a particular defect, the integration may include tools such as Design of Experiment (DOE). If manufacturers lack the expertise to use DOE, Thomas et al. (2009) simplified the DOE and integrated it into their LSS system. The integration may not necessarily include all the tools and techniques from both Lean Manufacturing and Six Sigma (Assarlind et al., 2013). Most LSS systems are inclined towards incorporating sophisticated statistical tools with little attention given to other decision making tools from Lean Manufacturing and Six Sigma. There is a need to explore a new LSS integration that combines other tools and techniques (Kumar et al., 2006).

Since SME constitutes the bulk of enterprise (Kumar, 2007) and there is growing importance of the supply chain issue together with the pressure from original equipment manufacturers (OEM) to perform, SMEs are compelled to implement management systems such as Six Sigma (Antony et al., 2005). However, the literature shows that SMEs are hesitant to implement management systems. A study conducted by Thomas and Webb (2003) concludes that only approximately 10% of SMEs in Wales have implemented some management systems. In a more recent survey reported by Kumar et al. (2014) only 36% of SMEs in Australia and

26% in the UK have moved beyond ISO 9000 certification to implement management systems because most SMEs consider ISO 9000 as a satisfactory final destination. Therefore, LSS in the context of SMEs should be further explored to encourage implementation as the knowledge in management systems is focused primarily on large organizations (Kumar et al., 2014).

Several reasons were cited in the literature for the reluctance of SMEs to adopt management systems. A major factor is resource constraint (Achanga et al., 2006, Chen et al., 2010; McAdam et al., 2014) which hinders the allocation of funds for external training and development of employees to adopt systems such as Lean and Six Sigma (Kumar et al., 2014). The survey of SMEs in Australia and the UK by Kumar et al. (2014) revealed the top three impeding factors to adopt management practices to be lack of resources (finance, human and time), knowledge and top management commitment. The constraint of resources is the main challenge especially for micro SMEs (Timans et al., 2016). Limited financial resources have caused companies to use in-house training and self-education, which are relatively inexpensive strategies compared to external consultation. Kumar et al. (2014) suggested that this move has led to 'conceptual confusion' (p. 6488) or lack of understanding of management practices. Therefore the development and application of any management system in SMEs should be feasible and fulfil practical requirements. A LSS model that works in the SME should capitalize on the existing capabilities of its employees, secure commitment from management and work within limited financial resources budgeted for improvement projects.

Few empirical studies have been published in the area of adopting LSS in SME (Albliwi et al., 2015, Timans et al., 2016). Sreedharan and Raju (2016) stressed that the adoption of LSS in SME is not widespread due to the reasons as mentioned.

One of the gaps identified by Albliwi et al. (2015) is the need of a roadmap to implement LSS and a customized LSS toolkit in the SME context.

1.3 Research objectives

This research aims to develop and implement a novel LSS model in the SME manufacturing industry with reference to two selected companies to improve their performance. As a whole, the objectives of this research are:

1. To determine suitable Lean Manufacturing and Six Sigma tools and techniques for the manufacturing SME.
2. To create a LSS model integrating the selected Lean Manufacturing and Six Sigma tools and techniques which are effective for the manufacturing SME.
3. To validate the developed LSS model in two case study companies.

1.4 Research Scope

LSS is the latest management system which integrates Six Sigma methodology, tools and techniques with Lean manufacturing tools and techniques to improve manufacturer's quality, cost and delivery. This research is directed towards the developing a model with suitable tools and techniques in the context of implementing LSS in SMEs. The challenge is on how LSS can be practiced in the SME industry despite its constraints. The developed model in this research will aid the industry to improve in QCD and the results of implementation are used to plan improvement actions.

1.5 Thesis outline

This thesis is divided into seven chapters. Chapter 1 provides the contextual background to this research on LSS, the problem statement and objectives of the research. The chapter prepares readers for what this research is all about and the aims to be achieved. Chapter 2 reviews the available literature on the history of quality management systems and their principles. The chapter also covers research on LSS models as well as their tools and techniques used in these models and implementation approaches.

This is followed by Chapter 3 which discusses the methodology undertaken in this research including steps in the model development process. Chapter 4 describes the developed LSS model with information on each stage of the model and the method to be applied in the two case studies selected. Techniques for data collection and data analysis approaches are detailed out in this chapter.

Subsequently, the step by step process of validating the developed LSS model in two SME companies is described in Chapter 5. A brief background of each company is presented first to provide more information on the case studies. Then, full details and elaborations of the implementation are put forward.

Chapter 6 presents a discussion of the validation results by focussing on the notable points of the model from the conceptual and structural perspectives. Finally, Chapter 7 concludes with the contributions of the study and recommendations for future work to fill the potential gap of knowledge in this field. Articles, journals and books cited in this thesis are numbered and listed down accordingly in the reference section at the end of this thesis.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter reviews the literature on management systems particularly LSS to build the appropriate knowledge foundation. It begins with an introduction and definitions of three fundamental objectives or core competencies for a business organization (Liker, 2004), namely, quality, costs and delivery (QCD). Several management systems are explained next in the chapter followed by the definition and philosophy of Lean Manufacturing and Six Sigma. This includes the tools, techniques and methodologies of these two management systems. Finally LSS as the latest management system developed is explained and a number of LSS models in the recent literature are presented.

2.1 Quality

Crosby (1996) defined quality as conformance of a product to requirements while Juran and De Feo (2010) defined quality as fitness of product for its purposes. On the other hand, Feigenbaum (1991) defined quality as the total composite product characteristics of marketing, engineering, manufacture and maintenance through which the product will meet the expectations of the customer. These definitions from literature unanimously agree on quality as the product characteristic that meets customer demands. The quality of a product is determined by the customers only (Feigenbaum, 1991) and is quantified based on the ratio of product characteristic to customer demands (Besterfield, 2004) (equation 2.1),