

Lean Six Sigma in Higher Education



Edited by
Jiju Antony

A Practical Guide for Continuous
Improvement Professionals
in Higher Education

Lean Six Sigma in Higher Education

Praise for Lean Six Sigma in Higher Education

'Higher Education institutions create true value when knowledge is being developed and transferred. Today's Higher Education institutions however comprise of many processes that are supportive to these purposes, but in itself do not create true value. This book is an excellent guide for managers and professionals in the Higher Education sector looking for process or product optimization within their institutes. It guides in separating value adding from non-value adding or even wasteful activities, and provides practical aids and tools for process optimization in the Higher Education sector.'

– **Bart A. Lameijer**, Assistant Professor and Senior Consultant,
University of Amsterdam Business School, Netherlands

'The importance of a long term strategic improvement framework for Higher Education has never been more necessary than today. Many attempts have been made by external policy makers in government, or internally by career administrators. Most have failed miserably to make any improvement in efficiency or effectiveness over the past 30 years. Costs have gone up and Quality has come down. Professor Jiju Antony and his team have gone outside of Academia to study the use of principles, tools and techniques with a proven track record in Manufacturing, business and service organisations. It is shown without doubt that Lean Six Sigma in Higher Education is needed right now! The book breaks down many myths and misconceptions about Lean Six Sigma and I encourage all administrators, leaders and policy makers to give this book a chance and read it with an open mind. Lean Six Sigma is a game-changer for Higher Education...and it needs to be given an opportunity to show its power.'

–**John Dennis**, Chairman International Lean Six Sigma Institute, UK

'This is another piece of art for the entire Lean Six Sigma global community! Higher Education (HE) is definitely an area full of improvement opportunities and Lean Six Sigma can be a critical component to change this game. The Editor of this book has addressed this topic brilliantly by showcasing a collection of articles including a dedicated chapter on the tools and techniques of LSS relevant to Higher Education context. This is a must-read book not only for academic leaders in HE but also for all continuous improvement practitioners that aim to promote a positive impact in this area.'

–**Marcelo Machado Fernandes**, MF Operational Excellence, ASQ
Certified Master Black Belt, Minitab Certified Trainer, Brazil

Lean Six Sigma in Higher Education: A Practical Guide for Continuous Improvement Professionals in Higher Education

EDITED BY

PROF. JIJU ANTONY

Heriot-Watt University, UK



United Kingdom – North America – Japan – India – Malaysia – China

Emerald Publishing Limited
Howard House, Wagon Lane, Bingley BD16 1WA, UK

First edition 2021

Copyright © 2021 Selection and Editorial matter by Jiju Antony.
Published under exclusive licence.

Copyright © 2021 Individual chapters by their respective authors

Reprints and permissions service

Contact: permissions@emeraldinsight.com

No part of this book may be reproduced, stored in a retrieval system, transmitted in any form or by any means electronic, mechanical, photocopying, recording or otherwise without either the prior written permission of the publisher or a licence permitting restricted copying issued in the UK by The Copyright Licensing Agency and in the USA by The Copyright Clearance Center. Any opinions expressed in the chapters are those of the authors. Whilst Emerald makes every effort to ensure the quality and accuracy of its content, Emerald makes no representation implied or otherwise, as to the chapters' suitability and application and disclaims any warranties, express or implied, to their use.

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN: 978-1-78769-930-4 (Print)

ISBN: 978-1-78769-929-8 (Online)

ISBN: 978-1-78769-931-1 (Epub)



ISOQAR
REGISTERED

Certificate Number 1985
ISO 14001

ISOQAR certified
Management System,
awarded to Emerald
for adherence to
Environmental
standard
ISO 14001:2004.



INVESTOR IN PEOPLE

Dedicated to my wife Frenie Antony and my daughter Evelyn Antony

This page intentionally left blank

Table of Contents

List of Figures	xv
List of Tables	xix
List of Contributors	xxi
Preface	xxiii
Acknowledgements	xxv
Chapter 1 An Overview of Lean Six Sigma	1
<i>Jiju Antony, Roger Hoerl and Ronald Snee</i>	
1.1 Introduction	1
1.2 Lean Six Sigma Yesterday – The History of Lean Six Sigma	2
1.2.1 The Launch of Six Sigma	2
1.2.2 A Brief History of Lean	3
1.2.3 The Marriage of Six Sigma and Lean	4
1.2.4 Lean Six Sigma Today – The Current State of Lean Six Sigma	5
1.2.4.1 Lean Six Sigma for Public Sector Organisations	5
1.2.4.2 Lean Six Sigma and Innovation	6
1.2.4.3 Standards for Lean Six Sigma Certification	6
1.2.5 Future of Lean Six Sigma Getting Better All the Time	7
1.2.5.1 Holistic Improvement Strategy and Methodology	7
1.2.5.2 Taking Advantage of Big Data	8

1.2.5.3 Sustaining Lean Six Sigma	8
1.2.5.4 Human Variation	9
1.2.6 Summary	9
References	10
Chapter 2 Academic Leadership – Their Culture and Characteristics	13
<i>Stephen Anthony and Jiju Antony</i>	
2.1 Introduction: What Is an Academic Institution?	13
2.2 The Changing World in the Twenty-first Century	14
2.3 The Future and the Need for Leadership	15
2.4 The Characteristics and Environment These Leaders Find Themselves in	17
2.5 Academic Leadership Defined – An Authors’ Perspective	20
References	21
Chapter 3 Lean Six Sigma in Higher Education: State-of-the-Art Findings and Agenda for Future Research	23
<i>Elizabeth A. Cudney and Sandy L. Furterer</i>	
3.1 Introduction	23
3.2 Methodology	24
3.2.1 Planning the Review	25
3.2.2 Conducting the Review	26
3.3 Literature Review	26
3.3.1 Six Sigma Approaches in Higher Education	26
3.3.2 Lean Approaches in Higher Education	29
3.3.3 Lean Six Sigma Approaches in Higher Education	32
3.4 Analysis of the Literature	36
3.5 Summary and Future Research	37
References	38
Chapter 4 Challenges in the Deployment of LSS in the Higher Education Sector: Viewpoints from Leading Academics and Practitioners	43
<i>Jiju Antony</i>	
4.1 Introduction	43

4.2	Viewpoints	43
4.3	Summary	52
Chapter 5 Readiness Factors for the Implementation and Deployment of Lean Six Sigma (or Operational Excellence) in Higher Education		53
<i>Jiju Antony and Scott P. Thomson</i>		
5.1	Introduction to Readiness and Readiness Factors	53
5.2	Readiness Factors for the Implementation and Deployment of LSS in HE	54
5.2.1	Visionary Leadership	55
5.2.2	Management Commitment and Resources	56
5.2.3	Focus on Customers	56
5.2.4	Linking Operational Excellence to University's Strategy	57
5.2.5	Organisational Culture	58
5.2.6	Selecting the Right People	58
5.3	Managerial Implications	59
5.4	Summary and Further Research Directions	59
	References	60
Chapter 6 Basic Lean Six Sigma Tools for Higher Education		61
<i>Jiju Antony and Vijaya Sunder M</i>		
6.1	Introduction to Tools of Lean Six Sigma	61
6.2	Lean Six Sigma Tools for Higher Education	62
6.2.1	Project Charter	62
6.2.2	Process Map	65
6.2.3	SIPOC	65
6.2.4	Value Stream Mapping	68
6.2.5	Cause and Effect Analysis (Fishbone Diagram)	71
6.2.6	Root Cause Analysis	73
6.2.7	Pareto Analysis	75
6.2.8	Histogram	77
6.2.9	Scatter Plot and Correlation Analysis	78
6.2.10	Run Charts	80
6.2.11	Control Charts	82
6.2.12	Standard Operating Procedures	85

6.2.13 Waste Analysis	86
6.2.14 In-frame and out-frame Diagram	91
6.2.15 Failure Mode and Effect Analysis	91
6.2.16 Box Plot	94
6.2.17 Hypothesis Tests	96
6.3 Summary	98
References	98
Chapter 7 Perceived Non-value Added Activities in the Research Grant Application Process – Through a Lean Six Sigma Lens	101
<i>Attracta Brennan and Mary Dempsey</i>	
7.1 Introduction	101
7.2 Key Drivers of the Research Grant Application Process	102
7.3 How Lean Six Sigma Can Support the Grant Application Performance	103
7.4 Challenges and Barriers within an Irish University’s Grant Application Process	104
7.5 Methodology	106
7.6 Key Findings	107
7.6.1 Online Survey Results	107
7.6.2 Semi-structured Interviews	109
7.7 Implications of the Study	116
7.8 Limitations of the Study	116
7.9 Recommendations and Directions for Further Research	116
7.10 Summary	119
References	121
Chapter 8 Voice of the Customer in Higher Education	125
<i>Scott P. Thomson and Jiju Antony</i>	
8.1 Introduction	125
8.1.1 What Is Voice of the Customer?	125
8.1.2 Why Does the Voice of the Customer Matter?	125
8.2 Defining Customers	126
8.3 Customers in the Higher Education Sector	128
8.3.1 Students	129

8.3.2 Parents of Students	129
8.3.3 Employers	130
8.3.4 Government	130
8.3.5 Alumni	130
8.3.6 Employees	131
8.4 VOC in Higher Education	131
8.4.1 The Current State of VOC in the Higher Education Sector	131
8.4.2 Why Should We Use VOC in Higher Education?	132
8.5 Stages to Develop a VOC Strategy	134
8.6 Case Study of VOC in Higher Education	138
8.7 Summary	139
References	140
Chapter 9 A Lean Six Sigma Maturity Model for Higher Education Institutions	141
<i>Stephen Anthony and Jiju Antony</i>	
9.1 Introduction	141
9.2 Research Methodology – Using Case Studies to Build a Model	142
9.2.1 Case Study Findings	142
9.2.1.1 Case Study 1	142
9.2.1.2 Case Study 2	142
9.2.1.3 Case Study 3	143
9.2.1.4 Case Study 4	144
9.3 Development of the Conceptual Model	145
9.4 Testing the Conceptual Maturity Model	148
9.5 Revised Lean Six Sigma Academic Maturity Model	149
9.6 Summary	149
References	159
Chapter 10 Lean Six Sigma Roadmap for Implementation in Higher Education Sector	161
<i>Vijaya Sunder M and Jiju Antony</i>	
10.1 Introduction	161
10.2 Awareness and Readiness	161

10.3	Preparation	163
10.4	Initialization: Team Formation, Projects Identification and Prioritisation	164
10.5	Implementation: LSS Project Management and Programme Governance	166
10.6	Sustenance	167
10.7	Summary	168
	References	169
Chapter 11	Six Sigma and Big Data	171
	<i>Chad Laux, Nimita Atal and John Springer</i>	
11.1	Introduction	171
11.2	The Data Revolution	171
11.3	What Is Big Data?	171
11.4	The Challenge of Big Data	172
11.5	Challenges of Six Sigma	173
11.6	The Six Sigma Big Data Proposition	173
	11.6.1 Define	176
	11.6.2 Measure	178
	11.6.3 Analyze	179
	11.6.4 Improve	179
	11.6.5 Control	180
11.7	Summary	181
	References	182
Chapter 12	Case Studies of LSS in Higher Education	185
12.1	Application of DMAIC in a HEI – An Improvement Project Case Study	185
	12.1.1 Introduction	185
	12.1.2 Application of DMAIC	185
	12.1.2.1 Define Phase	186
	12.1.2.2 Measure Phase	187
	12.1.2.3 Analyze	187
	12.1.2.4 Improve Phase	188
	12.1.2.5 Control Phase	190
	12.1.3 Key Outcomes and Lessons Learned	190
12.2	Application of LSS Methodology to Improve Service Process in Higher Education	192

12.2.1 Introduction	192
12.2.2 DMAIC Methodology	196
12.2.2.1 Define Phase	196
12.2.2.2 Measure Phase	199
12.2.2.3 Analyse Phase	206
12.2.2.4 Improve Phase	211
12.2.2.5 Control Phase	213
12.3 Application of DMAIC in Improving Library Utilisation in a HEI: A Case Study	215
12.3.1 Introduction	215
12.3.2 DMAIC Methodology	215
12.3.2.1 Define Phase	216
12.3.2.2 Measure Phase	216
12.3.2.3 Analyse Phase	216
12.3.2.4 Improve Phase	218
12.3.2.5 Control Phase	219
12.4 Summary	220
References	221
Index	223

This page intentionally left blank

List of Figures

Chapter 1

Figure 1.1.	Process View of Lean Six Sigma.	5
-------------	---------------------------------	---

Chapter 3

Figure 3.1.	Steps of Systematic Literature Review Methodology.	25
-------------	--	----

Chapter 6

Figure 6.1.	Lean Six Sigma Project Charter.	64
Figure 6.2.	Process Mapping Symbols.	66
Figure 6.3.	Sample Representation of Swim-lane Process Map.	66
Figure 6.4.	Example of a SIPOC Analysis in a Higher Education Setting.	69
Figure 6.5.	Common Value Stream Mapping Symbols.	70
Figure 6.6.	Current or Initial VSMM.	72
Figure 6.7.	Fishbone Diagram to Illustrate the Causes of Student Dissatisfaction with the University Computer Center.	74
Figure 6.8.	Root Cause Analysis Applied to a Postgraduate Research Application Process.	76
Figure 6.9.	Pareto Chart of Student Failures in Subjects.	77
Figure 6.10.	Histogram of Marks from a Postgraduate Course.	79
Figure 6.11.	Different Scenarios for Relationships between Two Variables on a Scatter Plot.	80
Figure 6.12.	Example of a Scatter Plot.	81

Figure 6.13.	Example of a Run Chart in a Higher Education Setting.	82
Figure 6.14.	Example of an Individual Control Chart.	83
Figure 6.15.	An Example of an Individual Control Chart.	85
Figure 6.16.	Standard Operating Procedures for Library Book Search Process.	87
Figure 6.17.	Eight Forms of Waste in a Higher Education Sector.	90
Figure 6.18.	Failure Modes and Effect Analysis.	93
Figure 6.19.	Revised Failure Modes and Effect Analysis after Remedial Measures Taken.	94
Figure 6.20.	Example of a Box Plot.	95
Chapter 7		
Figure 7.1.	Research Grant Application Support Tool.	119
Chapter 8		
Figure 8.1.	High-level Customer Definition Tool for a Higher Education Institution.	127
Figure 8.2.	Student-customer Definition Tool for a Higher Education Institution.	128
Chapter 9		
Figure 9.1.	A Lean Six Sigma Maturity Model for Academic Leaders and Institutions.	147
Figure 9.2.	The Final Maturity Model for Leaders Implementing Six Sigma in Academic Institutions.	150
Chapter 10		
Figure 10.1.	LSS Implementation Roadmap for Higher Education Institutions.	162
Chapter 11		
Figure 11.1.	Six Sigma Big Data Model.	177
Chapter 12		
Figure 12.1.	Input-Process-Output (IPO) Transcripts Process.	186
Figure 12.2.	Fishbone Analysis.	188

Figure 12.3.	Quality Improvements.	191
Figure 12.4.	Box Plot – Cycle Time of Transcript Ordering Process.	192
Figure 12.5.	Gemba – ‘before’ and ‘after’.	194
Figure 12.6.	Vision of Sponsored Program Services Office (SPS Website, 2018).	195
Figure 12.7.	Pre-award Proposal Submission Service Process Flow Chart.	195
Figure 12.8.	Hierarchy of Pre-award SPS Office.	197
Figure 12.9.	SIPOC Model of SPS Service.	200
Figure 12.10.	Number of Proposals in the Pre-award Area (2015–2016).	201
Figure 12.11.	Amount of Proposals in the Pre-award Area (2015–2016).	201
Figure 12.12.	Distribution of Prior to Deadlines.	202
Figure 12.13.	Time Series Plot of Late Submission Proposal (2015–2016).	203
Figure 12.14.	Distribution of PL Lead Time.	203
Figure 12.15.	Descriptive Statistics for Proposal Effort Score.	204
Figure 12.16.	Process Mapping for Proposal Submission Process in Pre-award Office.	205
Figure 12.17.	Descriptive Statistics Report of Processing Time.	205
Figure 12.18.	Categories 1–4 of Proposal Submission Prior to Deadline in Terms of Different Grant Types.	207
Figure 12.19.	Cumulative Percentage of Prior to Deadline Timeline.	207
Figure 12.20.	Fishbone Diagram for Imbalanced Workload.	209
Figure 12.21.	Pre-Award Service Timeline (SPS Website, 2018).	212
Figure 12.22.	Failure Mode of Effect Analysis (FMEA).	213
Figure 12.23.	Project Charter.	217
Figure 12.24.	Pareto Chart of Vital Few Causes.	218
Figure 12.25.	Box Plot of Project Metric before and after the Project.	220

This page intentionally left blank

List of Tables

Chapter 6

Table 6.1.	Data for Comparing the Average Marks of Students.	97
------------	---	----

Chapter 7

Table 7.1.	Semi-structured Interviews.	110
Table 7.2.	Recommendations.	118

Chapter 8

Table 8.1.	VOC Research vs Management Perceptions of Student Dropout Drivers.	139
------------	--	-----

Chapter 9

Table 9.1.	The Positions of the Interviewees from Case Study Organisations.	142
Table 9.2.	Linking the Evidence to the Themes.	146
Table 9.3.	Conceptual Model Testers and Reviewers.	148
Table 9.4.	Level 0 Characteristics and Descriptors.	151
Table 9.5.	Level 1 Characteristics and Descriptors.	152
Table 9.6.	Level 2 Characteristics and Descriptors.	153
Table 9.7.	Level 3 Characteristics and Descriptors.	155
Table 9.8.	Level 4 Characteristics and Descriptors.	156

Chapter 11

Table 11.1.	Comparison of Six Sigma and Big Data Principles.	175
-------------	--	-----

Chapter 12

Table 12.1.	Opportunities for Improvement.	189
Table 12.2.	Project Charter.	193
Table 12.3.	Categories 1 to 4 of Proposal Submission Prior to Deadline in Terms of Different Grant Types.	198
Table 12.4.	Regression Analysis for Proposal Effort Score and PI Lead Time with Final Submission Prior to Grant Deadline.	208
Table 12.5.	Identified Lean Wastes in Percentage of Proposals.	210
Table 12.6.	Percentage Reduction in Seven Typical Lean Wastes.	214

List of Contributors

Dr Stephen Anthony	Heriot-Watt University, UK
Prof. Jiju Antony	Heriot-Watt University, UK
Ms Nimita Atal	Purdue University, USA
Dr Attracta Brennan	National University of Ireland, Ireland
Dr Elizabeth A. Cudney	Maryville University of Saint Louis, USA
Mrs Mary Dempsey	National University of Ireland, Ireland
Dr Sandy L. Furterer	University of Dayton, USA
Mr Joe Healy	University College Cork, Ireland
Dr Roger Hoerl	Union College, USA
Dr Chad Laux	Purdue University, USA
Dr Na Li	Purdue University, USA
Mr John McNulty	University College Cork, Ireland
Mr Tom Murphy	University College Cork, Ireland
Ms Helen O'Donovan	University College Cork, Ireland
Mr Ronan O'Dubhghaill	University College Cork, Ireland
Mr Seamus O'Reilly	University College Cork, Ireland
Dr Ronald Snee	Snee Associates, USA
Dr John Springer	Purdue University, USA
Prof. Vijaya Sunder M	Indian School of Business, India
Mr Scott P. Thomson	Heriot-Watt University, UK

This page intentionally left blank

Preface

Businesses today are always on the lookout for ways to improve their bottom line by systematically eliminating waste from business processes as well as reducing unnecessary or undesirable variation in business processes which result in defects, errors or even failures leading to customer dissatisfaction. Lean Six Sigma (LSS) has become predominant in many fields. It is among the most common continuous improvement methodologies today. And while other industries, namely, manufacturing, service and some public healthcare services have adopted LSS to improve operations and focus on efficiency and effectiveness, Higher Education Institutions (HEIs) have largely been impervious to such continuous improvement efforts.

HEIs have been a cornerstone in educating society's leaders, an incubator for advanced technologies and an accelerator for economic development. The situation within the Higher Education (HE) sector is very similar to that of firms within the manufacturing and service industry – facing fierce competition, limited budget availability, government funding slashed, and students adopting a consumer approach to their learning. There are a few books on Lean in Higher Education, but the editor and contributors of this book would like to highlight the point to readers that both Lean and Six Sigma or even its integrated approach (Lean Six Sigma) can equally be applied to improve the efficiency and effectiveness of business processes in the HE sector. Moreover, only some problems can be tackled using the Lean approach in our view and hence the integrated approach can be more beneficial for tackling problems where variation is the primary issue (e.g. variation in turnaround times, variation in recruitment times of research staff for funded projects, etc.).

Higher education has become a competitive enterprise, with the characteristics of an organization that must compete for scarcity, as students replace funding from state resources. As universities compete for status and rank, the competitive nature can contribute toward a decline in the sense of academic mission, community and values. The ability to maintain the academy requires effort from a variety of resources, disciplines and ideas as the commercialization of higher education strains the social mission. LSS as a powerful Operational Excellence strategy is one contributing effort that can impact these trends of massification of the academy, and we hope the literature presented in this work will support a concerted effort to respond to the concern for quality in Higher Education.

This book is a collection of articles written by a number of contributors from three continents: Asia, Europe and North America. The book is a carefully edited

work by an academic and a practitioner of Operational Excellence based in the Higher Education sector. The book encompasses state-of-the-art literature review on LSS in HE sector, case studies of LSS in HE, tools of LSS which can be used in HE, challenges in the implementation of LSS in the HE setting, significance of Voice of the Customer, LSS Maturity Model for HE and emerging trends in the area. This book will benefit students, researchers, professional staff who would like to engage in process improvement projects in HE environments, and academics who would like to understand the concepts of Lean Six Sigma, as well as the challenges and barriers in the implementation and sustenance of this powerful Operational Excellence methodology. I firmly believe that the applications of LSS in HE will continue to grow over the years and this book is very timely. The book can be a great resource for training staff members in the HE sector or for self-study to understand the challenges in the implementation. Moreover, it provides the most powerful tools of LSS which can be used in Higher Education setting for problem-solving scenarios. Finally, I would like to thank all readers who are using this book for the LSS journey, and we wish the very best of luck with your endeavours.

Acknowledgements

I am deeply indebted to a number of people who, in essence, have made this book what it is today. First, and foremost, I would like to thank a number of contributors who have devoted their time in writing a chapter or chapters for the book. I am most grateful to the reviewers of the proposal and sample chapters for their invaluable suggestions that guided the preparation of this book. It is my sincere hope that by reading this edited book, you will find something new which will challenge your personal thoughts in a new way. Your suggestions and constructive feedback regarding the contents of the book will be taken into account, and I will do my best to overcome any shortcoming in the future editions of this book. Finally, I would like to express my sincere thanks to my family for their encouragement and patience as the book stole countless hours away from family activities. Finally, I take this opportunity to thank Emerald Publishing for their incessant support and forbearance during the course of the project.

This page intentionally left blank

Chapter 1

An Overview of Lean Six Sigma*

Jiju Antony, Roger Hoerl and Ronald Snee

1.1 Introduction

This chapter is an overview of Lean Six Sigma (LSS) as a powerful Operational Excellence (OPEX) methodology adopted by many Fortune 500 organisations around the world. OPEX has become an important strategy for many organisations today across the globe, despite of their nature and size. This includes manufacturers, financial service organisations, healthcare services, public sector organisations and most recently third sector organisations. Development of an effective OPEX strategy is a key factor for long-term success of modern organisations. Over the last decade, LSS has become one of the most popular and proven OPEX methodologies organisations ever witnessed in the past.

The concept of Lean Thinking (LT) developed from Toyota Production System (TPS) involves determining the value of any process by distinguishing value-added activities or steps from non-value-added activities or steps and eliminating waste so that every step adds value to the process. Lean focuses on efficiency, aiming to produce products and services at the lowest cost and as fast as possible (Antony, 2011). The commitment to LT must start at the top management level and should be cascaded down to various levels across the organisation to improve flow and efficiency of processes.

Six Sigma was developed at Motorola by an engineer Bill Smith in the mid-1980's. Six Sigma is a business improvement approach that seeks to find and eliminate causes of defects or mistakes in business processes by focussing on process outputs that are critical in the eyes of customers. Six Sigma principles can be used to shift the process average, help create robust products and processes and reduce excessive variation in processes which lead to poor quality (Shah, Chandrasekaran, & Linderman, 2008). The statistically based problem-solving

*This chapter is reproduced and adapted with kind permission from Emerald Publishing. The full citation of the chapter is Antony, J., Snee, R., & Hoerl, R (2017). Lean Six Sigma: Yesterday, today and tomorrow. *International Journal of Quality and Reliability Management*, 34(7), 1073–1093.

methodology of Six Sigma delivers data to drive solutions, delivering dramatic bottom-line results (Snee & Hoerl, 2007).

The term Lean Six Sigma was first introduced into literature around 2000, and LSS teaching was established in 2003 as part of the evolution of Six Sigma (Timans, Antony, Ahaus, & Solingen, 2012). Since that time, there has been a noticeable increase in LSS popularity and deployment in the industrial world, especially in large organisations in the West such as Motorola, Honeywell, General Electric and many others (Laureani & Antony, 2012; Timans et al., 2012) and in some small and medium-sized enterprises (Timans, Ahaus, Solingen, Kumar, & Antony, 2014). LSS has been defined by Snee (2010) as ‘a business strategy and methodology that increases process performance resulting in enhanced customer satisfaction and improved bottom line results’.

This chapter addresses three aspects of LSS: the yesterday, then the today and finally the tomorrow. The yesterday aspects of LSS will be presenting the background to LSS, history of LSS and also the rationale behind the integration of Lean and Six Sigma. The today aspects will be looking into a number of themes including, LSS for public sector, LSS and innovation and standards for LSS certification. The tomorrow aspects will be looking into the future trends of LSS, the importance of developing a holistic approach of OPEX in organisations, the synergy between Big Data and LSS for problem-solving, sustainability of LSS and the use of LSS for dealing with human variation.

1.2 Lean Six Sigma Yesterday – The History of Lean Six Sigma

1.2.1 The Launch of Six Sigma

Within this context, Motorola was facing extreme pressures from overseas competition, particularly Japan. While it is impossible to set a definitive date for the beginning of Six Sigma, around 1987 Bill Smith and others began improvement projects that in many ways looked similar to TQM projects. Eventually, Mikel Harry and others helped Smith formulate this approach into an overall business initiative aimed at protecting Motorola’s pager business. They named the initiative ‘Six Sigma’ based on the desire to reduce variation to the extent that specification limits for key process metrics were six standard deviations away from target.

Importantly, Six Sigma provided an overall ‘roadmap’ within Motorola, or problem-solving process, known as MAIC, which stood for measure, analyse, improve, control. MAIC effectively linked and integrated the individual tools. Therefore, employees could be trained in this one approach that was generic enough to be applied to a wide variety of problems, eliminating the need to reinvent the wheel with each new project. In addition, Six Sigma received clear management support, including supporting infrastructure, such as line items in budgets, resources, project selection systems, and so on.

Motorola achieved tangible results, and other organisations began to take notice. Honeywell and AlliedSignal, other organisations in similar markets to Motorola, launched Six Sigma initiatives around 1990. These also met with

success. However, it was when GE CEO Jack Welch loudly proclaimed that GE was jumping into the Six Sigma game in late 1995 that the initiative moved off the back pages of the business section to the front page of the newspaper. Welch told Wall Street analysts that Six Sigma would be the biggest initiative ever launched by GE, and that it would be his personal number one priority for the next 5 years (Welch, 2001). Even before results started to pour in, GE stock began to rise sharply, and many other companies started looking more closely at Six Sigma.

GE also played a very significant role in the development of Six Sigma as a methodology. After some projects stalled because there was a lack of clarity on the specific problem being addressed, and on the overall objectives, GE decided to add a 'Define' step at the beginning of the MAIC process and created the process we now know as DMAIC (Hoerl, 2001). The Define step became critical – a make or break step that often determined long-term success of the project. The need for careful problem definition is well-understood among those researching problem-solving in general.

Based in part on GE Capital's success, other financial institutions began Six Sigma initiatives. One of the most successful has been by Bank of America, which was publishing savings in the billions of dollars annually. Similarly, Commonwealth Health Corporation launched the first major Six Sigma deployment in healthcare in the late 1990s and produced millions of dollars of savings in the radiology department alone within a year (Snee & Hoerl, 2005).

In the late 1990s and early 2000s, a large number of organisations, in diverse industries, launched Six Sigma initiatives, including DuPont, Dow Chemical, 3M, Ford and American Express, to name just a few. The US military began major investments in Six Sigma at this time as well. Overseas, companies in Europe and Asia began to implement Six Sigma to varying degrees, particularly Korean companies such as Samsung.

1.2.2 A Brief History of Lean

Lean has had somewhat of a tangential development history to Six Sigma. Much of what we call Lean Enterprise today is based on the TPS (Womack, Jones, & Roos, 2007). Of course, the TPS has roots that go back to Henry Ford's development of the assembly line and Frederick Taylor's work. This approach to manufacturing cars, which emphasised removal of all types of waste, including non-value-added human motion, began taking shape at Toyota in the 1930s and has progressed ever since. Krafcik (1988) is generally credited with the first use of the term 'Lean manufacturing'.

In our view, there is some confusion between Lean and the TPS, in that some authors use the term Lean to refer to any business practice utilised by Toyota, while others use Lean to refer to a specific set of principles and tools (George, 2002). For clarity, we will refer to Lean Enterprise as the set of principles and accompanying tools outlined in George (2002), MacInnes (2002) and other sources that see Lean as based on TPS, but having a unique identity from Toyota.

While Six Sigma focused on collecting data in order to apply statistical methods to solve baffling problems, Lean was generally applied in a more knowledge-based approach, by applying time-tested principles, such as reducing inventories, pull versus push production systems, line of sight, continuous versus batch processing, cell manufacturing and so on, to reduce waste and enhance productivity. That is, while knowledge and data were needed by both methodologies, one can be reasonably accurate in generalising that Six Sigma was more data oriented and Lean was more oriented on applying proven principles based on knowledge and experience. All processes have waste, and sound principles can be applied outside of manufacturing to reduce waste and improve productivity. For example, the principle of line of sight – being able to physically see the production line – can be applied to financial transactions, in that those working in the financial process should have process transparency, in order to be able to ‘see’ the process in operation, at least electronically. Workflow-based IT systems are one example of providing line of sight to financial systems.

1.2.3 The Marriage of Six Sigma and Lean

Because both Six Sigma and Lean had produced tremendous results, but had limitations, some type of integration of the two was appealing and made intuitive sense. Books and seminars on the topic of LSS began to appear in the early 2000s, such as [George \(2002\)](#). As noted previously, Lean is not well suited to resolving complex problems that require intensive data analysis and advanced statistical methods.

Conversely, those implementing Six Sigma found that not every problem needed several months of data collection to resolve. Do we really need to collect data for 3 months in order to repave a parking lot that has potholes? Quality professionals found that Lean principles could be broadly and effectively applied with minimal data collection and achieve immediate benefits. Then, for more complex problems requiring intense data analysis, Six Sigma could be utilised. In our view, the key questions to ask when considering a Six Sigma versus Lean approach are

- Is the solution known or unknown?
- Is the root cause of the problem believed to be in a value-adding step in the process, or in the linkages between value-adding steps?

We have found that in many Lean applications, what must be done is known; we just need a method and tools to implement the known solution. This is because Lean is primarily a set of known principles, as opposed to data analysis techniques. The second question points to the fact that the principles of Lean are focused on the flow of information and material through the process. Therefore, if the root cause of the problem is a flow issue – in the linkages between value-adding steps – Lean is likely to work well. Conversely, if the root cause of the problem is in a value-adding step, Six Sigma is more likely to succeed for such problems. [Fig. 1.1](#), from [Snee and Hoerl \(2007\)](#), illustrates this point.

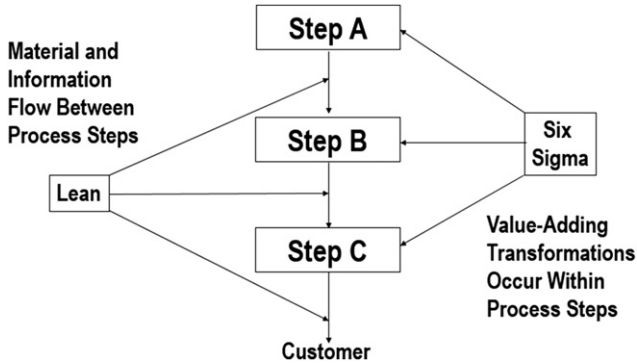


Fig. 1.1. Process View of Lean Six Sigma.

The key point is that organisations need to avoid having ‘favorite’ methods that they apply to all problems, even if the method is not suited for that particular problem. Integrating Six Sigma and Lean into a broader approach called LSS has enabled many organisations, including GE and many of those mentioned previously, to solve more problems quicker and enhance the bottom line faster. It can be considered state of the art in improvement at the time of this writing.

1.2.4 Lean Six Sigma Today – The Current State of Lean Six Sigma

This section presents the today aspects of LSS which includes LSS for the public sector, the link between LSS and Innovation, standards for LSS certification and the current burning issues around the certification process.

1.2.4.1 Lean Six Sigma for Public Sector Organisations

Although Lean has been widely used by many public sector organisations in Europe, the use of Six Sigma and LSS are in their early stages. The challenge for many public sector organisations today is to reduce spending, while retaining or even improving the efficiency and effectiveness of service delivery. Using LT, we need to reduce waste and maximise the value-added activities for customers, and by using Six Sigma, we need to deliver consistent services by reducing process variation. Some of the benefits of utilising LSS in public sector organisations include

- Costs associated with fire-fighting and misdirected problem-solving efforts with no structured or disciplined methodology could be significantly reduced
- Increased understanding of the VOC (Voice of the Customer) and the associated CTQs (critical-to-quality characteristics, e.g., teaching quality of a professor in a university sector) which will have the greatest impact on customer satisfaction

- Reduced number of non-value-added operations through systematic elimination, leading to faster delivery of service, faster lead time, faster cycle time to process critical performance characteristics to customers and stakeholders, etc.
- Transformation of organisational culture from being reactive to proactive thinking/mindset
- Many managers lack statistical knowledge and the ability to apply statistics to problem-solving. LSS provides a fundamental framework for managers to use practical and proven applied statistical tools and techniques for problem-solving in public sector organisations
- Greater responsiveness and flexibility to meet customer needs

1.2.4.2 Lean Six Sigma and Innovation

Xerox has seen impressive results by pairing its LSS initiatives and innovation teams together to drive product development. Recently, the use of LSS techniques during an innovation project resulted in millions of dollars in total savings and nearly 50% return on investment for Xerox (Hildebrand, 2010). As Bisgaard (2008) explains, innovation can be either incremental innovation – making modest enhancements to an existing product or service – or radical, ‘disruptive’ innovation – delivering something totally new to the marketplace. Federal Express, when it introduced overnight mail delivery years ago, was also clearly innovative in a radical way, as no other overnight mail delivery service existed at the time, and many thought such a service would be impossible to implement (Hoerl & Gardner, 2010).

Antony et al. (2014) have carried an exploratory study in 10 UK-based companies to explore the relationship between LSS and product/process/service innovation. A multiple case study design was employed across manufacturing and service companies in the United Kingdom of varied size. The companies participated in the study have been involved in LSS implementation for a minimum of 3 years. The findings of the study have clearly indicated that companies engaging with LSS initiatives experience a positive effect of LSS on Incremental Innovation and Innovation Capability.

The study has also looked at the perceived enablers and hinders of innovation in LSS organisations. The perceived enablers include senior management openness, recognition of the best ideas, a communication system that allows the free flow of ideas, top management attention and their support, culture of the organisation, a learning environment and so on. The perceived hinders include organisations with no learning culture, silo mentality, poor or weak leadership that does not support innovation, poor communication, etc.

1.2.4.3 Standards for Lean Six Sigma Certification

LSS has no globally accepted standard for certification: the proliferation of schools, organisations and training providers that now offer some level of certification has led to a wide variation in assessment criteria, leaving many hiring managers, recruiters and continuous improvement leaders sceptical of external

certifications. Some certifications currently existing on the market do not require to prove some technical competence or to show project work: you can indeed pay to attend a small course and get a certificate, without ever actually doing a project (Laureani & Antony, 2011). In authors' opinion, American Society for Quality Certifications represents a third party and has gained acceptance for Master Black Belts as well as Black Belts and Green Belts.

The actual set of tools and theories in the background of LSS, which ultimately stems from the Quality Management and Quality Engineering gurus like Deming, Juan, Crosby, Ishikawa, Feigenbaum and Taguchi, are the same across industries, hence a common Body of Knowledge. The differences in application of the principles should be reflected in the Body of Experience and the type of projects used for certification. As in any other discipline, the evolution of the field, and the emphasis on application of the tools, is such that only with constant practice can a certified practitioner retain mastery of the tools: as a result, it is advisable to require practitioners to either recertify or remain involved in professional development activities to retain certification (Laureani & Antony, 2011).

1.2.5 Future of Lean Six Sigma Getting Better All the Time

Much has changed and much has been accomplished in the world since Six Sigma was introduced by Motorola in 1987. Many organisations around the globe, large and small, have used first Six Sigma and now LSS to become more successful: quality has been improved, delivery times have been reduced, waste has been decreased and customer satisfaction has been enhanced. A critically important by-product of this work has been the saving of billions of dollars around the world. LSS has benefitted organisations of all types, including manufacturing, service, healthcare, government, nonprofits and education. The expansion of the LSS methodology and application of the approach to improvement will continue as new needs and opportunities are encountered. In this section, the authors will be providing some of the future trends of LSS, which include importance of a holistic approach to OPEX in any organisation irrespective of its size and nature, integration of LSS with Big Data for effective problem-solving, sustainability of LSS and the use of LSS for dealing with human variation.

1.2.5.1 Holistic Improvement Strategy and Methodology

Holistic improvement views an organisation as a system which can be optimised (Snee & Hoerl, 2007, 2019). A holistic improvement system can successfully create and sustain significant improvements of any type, in any culture for any type of organisation. Parsing this definition we find 'create and sustain' referring to infrastructure – management systems and resources, continuous improvement culture, leadership development and related issues. Here 'significant improvements' refer to improving performance as measured quality, cost, delivery and customer satisfaction in a way that improves the bottom line. 'Any type of improvement' refers to improving any measure of performance including flow, variation, optimisation, design, improvement and control. 'Any culture' refers to

any country around the globe and any function within an organisation. ‘Any organisation’ refers to manufacturing, service, public sector and third sector.

The holistic improvement methodology integrates Lean principles with LSS methods and other approaches (e.g., Kaizen, Agile, etc.) that are used as the problem at hand requires. The nature of the problem should guide identification of the approach, rather than assuming that one methodology is ideal for all problems. As the old saying goes, ‘*if all you have is a hammer, every problem looks like a nail*’. Project identification and selection becomes a critical step, for in this step, the approach to be used to solve the problem becomes apparent. The organisation’s improvement system must be robust enough to handle any problem the organization encounters in the course of its improvement work. Integration of multiple methodologies is clearly required.

1.2.5.2 Taking Advantage of Big Data

Data mining has been in vogue for the last 15–20 years. Around 2005, the trend picked up steam with advent of the ‘Big Data’, which was and will continue to be fuelled by the ubiquitous availability of the Internet and IT hardware and software (Davenport & Harris, 2007). We are now talking about terabytes and petabytes of data, and we now have the software that can help us ‘tame’ Big Data. The Big Data focus, as with all new developments, is good news–bad news situation.

The Big Data revolution is breathing new life into Lean principles and Six Sigma standards. In effect, it provides back door entry into a data-rich realm of reasoning that can unlock infinite efficiencies and savings when approached in the right way. Big Data offers the opportunity for professionals to solve problems previously thought to be unsolvable. While much progress has been made in medical research and Internet marketing, one area overlooked to date is the use of Big Data in the design and improvement of products, services and process quality. Customer surveys can help us better understand customer needs and experiences. The collection of manufacturing data and integrating it with customer data can help improve products and processes.

The bad news is that most data used in data mining and Big Data studies are what are called ‘observational data’, in that they are passively collected, rather than produced by carefully designed and randomised experiments. Such data require a close assessment of the data pedigree as typically no study design is used to assure that good data and the right data needed to solve the problem are collected (Snee & Hoerl, 2012). These data often have many limitations which need to be taken into account. On the other hand, many have adopted a philosophy of ‘Big Data + Fancy Algorithms = Great Results’.

1.2.5.3 Sustaining Lean Six Sigma

Hardly a month goes by without seeing one or two articles related to sustaining improvement. There are two critical issues within this macro problem: sustaining the improvement initiative itself and sustaining the results of individual improvement projects. There are many reasons for the lack of sustainment including the new procedures not followed, important projects not identified and