

CRANFIELD UNIVERSITY

School of Aerospace, Transport and Manufacturing

PhD

Academic Year 2008 - 2015

P. Ayeni

Enhancing competitive advantage through successful Lean realisation within the Aviation  
Maintenance Repair and Overhaul (MRO) industry

Supervisors: - Dr P.D. Ball & Professor T.S. Baines

October, 2015

## ABSTRACT

**Purpose:** Lean is increasingly being applied within the aviation Maintenance and Repair (MRO) Industry to mitigate industry challenges. This Lean application is premised on its success within other industrial contexts particularly the automotive industry. Furthermore, many organisations within automotive industry have attributed their enhanced competitive positioning to the Lean application. Indeed, Toyota (a pioneer of Lean) present Lean as a key proponent to its global success. However, with literature suggesting that there cannot be a direct transference of Lean from one industry to another and with the MRO having distinct characteristics different from the automotive industry, this research seeks to present how competitive advantage can be achieved through successful Lean realisation.

**Design/Methodology/Approach:** The status of MRO Lean engagements presented is first presented based on the syntheses of literature review and empirical study (facilitate by an industry-wide survey). The means through which the MRO realises its value proposition is established and the structural assessment of the MRO industry as it pertains to competitiveness is also defined. The role of Lean in enhancing the value delivery system to enhance competitive positioning is operationalised through a case study.

**Findings:** Using Porter's forces of competition, this research establishes the competitive MRO landscape revealing the distinct characteristics of the MRO industry and how Lean can be accurately appropriated to enhance competitive advantage. The MRO Value Delivery System (VDS) is also delineated providing the complete system within which Lean is to be deployed (as opposed to the prevalent limited application of Lean in operational context alone). The case exemplar successfully validates and operationalises the approach to Lean application within MRO to enhance competitive advantage.

**Research Limitations:** A case study example was used for this research, and whilst the outcomes were consistent with the research proposal, it still requires wider validation.

**Practical and Social Implications:** This research demystifies and helps MRO organisations in assessing their Lean engagements but also in provide a roadmap and informs their strategy in improving their competitive status through Lean realisation.

## ACKNOWLEDGEMENTS

I will like to thank Dr P Ball (who was my supervisor through this programme) for his patience, support and assistance which have proved to be invaluable. The thoroughness of this assessment coupled with the level of critical thinking and analyses which he has subtly developed in me has transformed the quality of my work and subsequently contributed towards to my career advancement. Further acknowledgement and immense gratitude also goes to Professor T.S. Baines of Aston Business School (formerly of the school of Applied Sciences, Cranfield University) for the clarity of thought and passion which was very infectious and a source of strength through this research programme.

The author will also like to express his gratitude for the engagement and assistance from all the organisations that contributed to the success of this research particularly Lufthansa Technik Landing Gear Service, (UK). Further acknowledgement also goes to Jonathan Rumble, Michael Schiesari and Dr S. Podgoric for their contribution and kind words of encouragement through this research process.

Finally, this research will not have been possible but for the love, motivation, support and strength of dear friends and family. The author is eternally grateful for a praying mother, a model father and a brother and sister whose unflinching vote of confidence has been truly invaluable. Thank you.

# CONTENTS

## Table of Contents

ABSTRACT.....	1
ACKNOWLEDGEMENTS.....	2
CONTENTS.....	3
LIST OF PUBLICATIONS BY AUTHOR.....	9
LIST OF FIGURES .....	10
LIST OF TABLES.....	12
GLOSSARY OF TERMS .....	14
1. INTRODUCTION.....	15
1.1 Introduction to the Research.....	15
1.2 Overview of Research Aim and Objectives.....	19
1.3 Overview of the Research Programme .....	19
1.4 Overview of the Research Contribution.....	22
1.5 Overview of the Thesis Structure.....	23
2. INDUSTRIAL CONTEXT: LEAN IN THE AVIATION MAINTENANCE REPAIR AND OVERHAUL INDUSTRY – LITERATURE REVIEW.....	26
2.1 A Description of the MRO Industry .....	28
2.2 The Objective of the MRO industry.....	29
2.3 Characteristics the MRO Industry.....	31
2.3.1 Variability in Demand.....	31
2.3.2 Uncertainty in the work-scope.....	32
2.3.3 Uncertainty in Supply.....	32
2.3.4 Cannibalisation.....	32
2.4 Classification of the MRO industry .....	33
2.4.1 MRO categorisation based on type-function.....	36
2.4.2 MRO categorisation based on ownership and organisational Structure.....	38

2.4.3	MRO industry described within Product-Centric Service terms .....	39
2.5	Description of ‘Lean’ .....	41
2.6	Lean <i>thinking</i> within the MRO industry .....	44
2.7	Assessing of the status of Lean in MRO .....	47
2.8	Current literature of Lean in Aviation MRO context.....	48
2.9	Presentation of Gaps from Literature.....	52
2.9.1	Prevalent interpretation of Lean.....	52
2.9.2	Motivation for the adoptions of Lean.....	53
2.9.3	Prevalent focus of Lean implementation.....	54
2.9.4	Extent of Lean adoption.....	55
2.9.5	Prevalent strategy for Lean implementation.....	56
2.9.6	Critical success factor for Lean implementation.....	58
2.9.7	Prevalent Inhibitors for Lean advancement in MRO .....	59
	Lack of comprehensive understanding of Lean .....	59
	Appropriating Lean incorrectly to address challenges characteristic of the MRO industry. ....	61
2.9.8	Strengths and Weakness of Existing Literature .....	62
2.10	Discussion .....	63
2.11	Chapter Summary .....	65
3.	RESEARCH PROGRAMME, AIM AND OBJECTIVES .....	68
3.1	Research Problem .....	68
3.2	Aim and Objectives.....	72
3.3	Development of Research Programme.....	72
3.3.1	Phase 1: Understand and establish the status of MRO Lean engagements. ....	75
3.3.2	Phase 2: Delineate the means through the MRO value proposition is delivered.....	75
3.3.3	Phase 3: Establishing the competitive landscape of the MRO industry, the competitive routes and the role of Lean within this backdrop. ....	76
3.3.4	Phase 4: Validate the approach to Lean application within MRO to enhance competitive advantage. ....	77

3.4	Chapter Summary .....	77
4.	EMPIRICAL STUDY INTO THE MRO LEAN STATUS AND APPROACH.....	79
4.1	Phase 1 Review: Motivation for empirical study .....	81
4.2	Empirical Study: development of research questions. ....	81
4.3	Questionnaire Development and Methodology .....	83
4.3.1	Questionnaire Design.....	83
4.3.2	Overview of the Questionnaire questions .....	84
4.3.3	Pilot and Refine Questionnaire .....	86
4.4	Identification of the Population to be Surveyed.....	88
4.5	Questionnaire Execution .....	90
4.6	Presentation of Results.....	91
4.7	Key Findings Emerging from Survey Results .....	92
4.7.1	Structural Characteristics.....	104
4.7.2	Infra-structural characteristics:.....	109
4.8	Discussion.....	114
4.9	Review and summary of the motivation of the empirical study. ....	116
5.	ESTABLISHING HOW THE MRO REALISES ITS VALUE PROPOSITION .....	121
5.1	Introduction.....	122
5.2	Developing the MRO Value Delivery System (VDS) .....	122
5.3	Delineating the MRO Value Delivery System from the Business Model Framework .	126
5.4	Dimensions to the MRO Value Delivery/Creation System .....	132
5.5	MRO Value Delivery System – Strategic Dimension.....	134
5.5.1	Strategic Dimension - Corporate Logic .....	134
5.6	MRO Value Delivery System – Economic Dimension.....	136
5.6.1	Economic Dimension - Assets .....	137
5.6.2	Economic Dimension – Capabilities .....	139
5.7	MRO Value Delivery System – Operation Dimension.....	140

5.7.1	MRO Operational System - Principal Constructs of the Key Business Decision Areas (kbda)	142
5.7.2	Structural Characteristics of Operation .....	144
5.7.2.1.	Process and Technology.....	144
5.7.2.2.	Capacity .....	144
5.7.2.3.	Facility .....	145
5.7.2.4.	Supply Chain Positioning.....	145
5.7.2.5.	Planning and Control .....	145
5.7.3	Infrastructural Characteristics of Operation .....	145
5.7.3.1.	Human Resources .....	145
5.7.3.2.	Quality Control .....	146
5.7.3.3.	New Product / Service Introduction.....	146
5.7.3.4.	Performance Measurement.....	146
5.7.3.5.	Supplier Relations .....	147
5.7.3.6.	Customer Relations .....	147
5.8	Critical Resources of the MRO Value Delivery System.....	147
5.9	Overview and Chapter Summary .....	149
6.	COMPETITIVE ADVANTAGE AS IT PERTAINS TO MRO .....	152
6.1	Structural analysis of the MRO industry.....	153
6.1.1	The threat of New Entrants .....	155
6.1.2	Bargaining Power of Buyers (Consumers).....	165
6.1.3	Threat of Substitute Products .....	171
6.1.4	Bargaining Power of Suppliers .....	172
6.1.5	Rivalry Among Existing Competitors.....	176
6.2	Achieving Sustainable Competitive Advantage through Lean .....	183
6.2.1	Lean and Agile Production .....	185
6.3	Reconciling Between the ‘ <i>External</i> ’ Factors and the ‘ <i>Internal</i> ’ Value Delivery System	189

6.4	Overview of the MRO Business Environment.....	192
6.5	Strategic Response: Dominant Means of Mediation and associated Success Factors	194
6.5.1	Means of Mediation – Cost Leadership .....	194
6.5.2	Cost Leadership Strategy Success Factor: Cost of Production Inputs.....	197
6.5.3	Cost Leadership Strategy Success Factor: Economies of scale .....	199
6.6	Means of Mediation: Product (or ‘Offering’) Differentiation .....	202
6.7	Means of Mediation: Best Solution .....	204
6.8	Competitive Priorities and Performance Measurement.....	204
6.9	Relevance of Performance Measures to Lean Realisation .....	206
6.10	Chapter Summary .....	208
7.	CASE STUDY OPERATIONALISING THE APPLICATION OF LEAN WITHIN THE MRO VALUE DELIVERY SYSTEM (VDS) .....	212
7.1	Validation Protocol .....	213
7.1.1	Defining the assessment criteria and data collection method. ....	213
7.1.2	Semi structured interviews. ....	214
7.2	Case Study Selection .....	215
7.3	Results from the semi-structured interview. ....	217
7.4	Analysis and discussion of the results from the semi-structured interview.....	226
7.5	Using the Failure Mode Effect Analysis (FMEA) to validate the <i>utility</i> of the Value Delivery System.....	227
7.6	The interaction between FMEA and the Value Delivery System .....	230
7.7	Modified FMEA Methodology to Enhance Competitive Advantage.....	234
7.8	Case study – Applying the FMEA on LTLGS.....	238
7.9	Analysis of the outcome from the FMEA case study .....	248
7.10	Chapter Summary .....	249
8.	CONCLUSION.....	250
8.1	Overview of Research Aim, Objectives and Programme .....	252
8.2	Gaps in knowledge.....	253

8.3	Summary of the contribution to knowledge.....	260
8.3.1	Primary Contribution to knowledge .....	260
8.3.2	Secondary Contributions to Knowledge .....	261
8.4	Limitations of Research Programme.....	263
8.5	Recommended Future Work .....	264
8.6	Concluding Remarks.....	265
9.	REFERENCE.....	266
10.	APPENDIX.....	286

## LIST OF PUBLICATIONS BY AUTHOR

- Ayeni P., Baines T.S., Lightfoot H., Ball P., (2011). “State-of-the-art of 'Lean' in the Aviation Maintenance, Repair, and Overhaul industry”. Proceedings of the Institution of Mechanical Engineers Part B Journal of Engineering Manufacture, 225(11):2108-2123.
- Ayeni P., (2013) “Keep Planes Flying – Lufthansa Technik Landing Gear Service (UK). Preceedings of the International Lean Summit, Lean Transformation: Frontiers and Fundamentals, Wokefield Park, Reading, UK, 5th - 7th November 2013.  
([http://www.leanuk.org/pages/event\\_summit\\_2013.htm](http://www.leanuk.org/pages/event_summit_2013.htm))
- Peter Ayeni, Peter Ball, Tim Baines, (2016) "Towards the strategic adoption of Lean in aviation Maintenance Repair and Overhaul (MRO) industry: An empirical study into the industry's Lean status", Journal of Manufacturing Technology Management, Vol. 27 Iss: 1, pp.38 – 61.

## LIST OF FIGURES

Figure 1.1: Overview of Research Programme.....	20
Figure 1.2: Thesis Structure .....	25
Figure 2.1: Overview in establishing the state-of-the-art of Lean in aviation MRO as presented in this chapter.....	27
Figure 2.2: Development of literature review questions relating the state-of the-art of Lean in aviation MRO .....	48
Figure 3.1: Structure of research programme .....	74
Figure 4.1: Table describing contents of the chapter.....	80
Figure 4.2: Industrial and academic review of the questionnaire via an iterative pilot process. ....	87
Figure 4.3: Spread of companies identified for the empirical (survey) study.....	90
Figure 4.4: Survey response according to industry sector: Heavy Maintenance Visit (HMV); Engine Overhaul; Component Overhaul; Line Maintenance; Avionics; Major Modifications, Retrofits and Conversions.....	92
Figure 4.5: Overview of typical MRO operations.....	93
Figure 4.6: MRO Offering – Operation footprint (Component Sector).....	94
Figure 4.7: MRO Offering – Operation Footprint – Engine Sector.....	94
Figure 4.8: MRO Offering – Operation footprint (Line Maintenance).....	95
Figure 4.9: MRO Offering – Operation footprint (Avionics).....	95
Figure 4.10: MRO Offering – Operation footprint (HMV Sector).....	96
Figure 4.11: MRO Offering – Operation footprint (Mod & Retrofits).....	96
Figure 4.12: The spread of the type of tools adopted by the MRO industry.....	98
Figure 4.13: Graph showing the relationship between the number of Tools & Practices applied with the number of employees in the company.....	100
Figure 4.14: The outcome of Lean implementation within generic key performance measuring areas .....	101
Figure 4.15: Graph showing the rating of Lean’s influence within MRO Structural characteristics of operation.....	104
Figure 4.16: Graph showing the rating of Lean’s influence within MRO Infra-structural characteristics of operation. ....	109
Figure 4.17: Profiling the performance status of each characteristic of operation .....	113
Figure 4.18: Establishing the status of MRO Lean Engagements (comparing Literature and Empirical perspectives .....	118

Figure 5.1: Characteristics of the Value Delivery System model (Yung & Chan, 2003) [Adapted].....	124
Figure 5.2: Unified business model framework (Al-Debei & Avison, 2010).....	128
Figure 5.3: Bringing order to the different description of the MRO business Model.....	130
Figure 5.4: Overview of MRO Value Delivery Framework.....	133
Figure 5.5: Understanding the aspects to the Strategic Dimensions of the MRO value delivery system .....	135
Figure 5.6: Understanding the aspects to the Economic Dimension to the MRO Value Delivery System.....	137
Figure 5.7: Understanding the aspects to the Operational Dimension to the MRO Value Delivery System.....	142
Figure 5.8: Understanding the aspects to the MRO Value Delivery System.....	151
Figure 6.1: Five competitive forces that determine the industry profitability (Porter, 1985).....	154
Figure 6.2: Competitive profiling between Company A and Company B.....	192
Figure 7.1: An overview of the FMEA approach interacts with the value delivery system (VDS) (Sawhney et al., 2010) .....	232
Figure 7.2: An overview of the modified FMEA for VDS (Sawhney et al., 2010). .....	235
Figure 8.1: Establishing the status of MRO Lean Engagements (comparing Literature and Empirical perspectives .....	256
Figure 8.2: Understanding the aspects to the MRO Value Delivery System .....	258
Figure 8.3: Overview of the Modified FMEA approach for value delivery system (VDS).....	259

## LIST OF TABLES

Table 2.1: MRO-type Functions and Logistics .....	38
Table 2.2: Literature keyword search results .....	49
Table 2.3: Key publications identified in the review of the state-of-the-art of Lean in the MRO industry .....	51
Table 2.4: Summary of key Findings.....	67
Table 4.1: Breakdown of the companies identified for the survey according to the MRO sector they belong to. ....	90
Table 4.2: Characteristics of operation (Baines et al., 2009) .....	103
Table 4.3: Summary of the Findings from the empirical study .....	117
Table 5.1: Characteristics of operation Baines et al. (2009).....	143
Table 6.1: Threat of New Entrants as it applies with ‘Economies of scale’ .....	158
Table 6.2: Threat of New Entrants as it applies to ‘Product differentiation’ .....	159
Table 6.3: Threat of New Entrants as it applies to ‘Capital Requirement’ .....	160
Table 6.4: Threat of New Entrants as it applies to ‘Other Cost Advantages’ .....	161
Table 6.5: Threat of New Entrants as it applies to ‘Switching Cost’ .....	162
Table 6.6: Threat of New Entrants as it applies to ‘Distribution Networks’ .....	163
Table 6.7: Threat to MRO competitive structure: New Entrants.....	164
Table 6.8: Bargaining Power Comparison between Military and Commercial buyers .....	170
Table 6.9: Bargaining power of Suppliers as it applies to the main buyer group (Military and Commercial).....	175
Table 6.10: Porters (1985) Competitive Forces: Rivalry among existing competitors .....	182
Table 6.11: Key Characteristics of Operation Baines et al. (2009).....	196
Table 6.12: Sample Balance Score Card (BSC) .....	207
Table 7.1: Key points raised from semi-structured interview (case study) .....	218
Table 7.2: Key points raised from semi-structured interview (case study) .....	219
Table 7.3: Key points raised from semi-structured interview (case study) .....	220
Table 7.4: Key points raised from semi-structured interview (case study) .....	221
Table 7.5: Key points raised from semi-structured interview (case study) .....	222
Table 7.6: Key points raised from semi-structured interview (case study) .....	223
Table 7.7: Key points raised from semi-structured interview (case study) .....	224
Table 7.8: Key points raised from semi-structured interview (case study) .....	225
Table 7.9: Case Study using the modified FMEA to validate LTLGS Lean application to enhance competitive advantage through its VDS – Personnel Resource (Sawhney et al., 2010) [Adapted]....	241

Table 7.10: Case Study using the modified FMEA to validate LTLGS Lean application to enhance competitive advantage through its VDS – Equipment Resource (Sawhney et al., 2010) [Adapted].. 243

Table 7.11: Case Study using the modified FMEA to validate LTLGS Lean application to enhance competitive advantage through its VDS – Material Resource (Sawhney et al., 2010) [Adapted]..... 245

Table 7.12: Case Study using the modified FMEA to validate LTLGS Lean application to enhance competitive advantage through its VDS – Schedule Resource (Sawhney et al., 2010) [Adapted]..... 247

Table 8.1: Summary of key gaps identified from the literature review ..... 254

Table 8.2: Summary of key findings identified from the empirical study ..... 255

## **GLOSSARY OF TERMS**

MRO	Maintenance Repair and Overhaul
OEM	Original Equipment Manufacturer
TPS	Toyota Production System
KBDA/V	Key Business Decision Areas/Variables
TAT	Turn-Around-Time
JIT	Just-In-Time
KAIZEN	Continuous Improvement refers (Japanese)
MUDA	Waste (Japanese)
WIP	Work in Progress/Production
PMA	Parts Manufacture Approval
VDS	Value Delivery System
FMEA	Failure Mode Effects Analysis
SOP	Standard Operating Practices (or Procedures)
AOG	Aircraft on Ground

## 1. INTRODUCTION

This chapter presents the reasons and rationale for the undertaking of this research (section 1.1). It then presents an overview of the research aim and objectives (section 1.2). The methodology of the research is also summarised (section 1.3) and the contribution of this work to knowledge is outlined in (section 1.4). The final section of this chapter illustrates the structure and composition of the thesis (section 1.5).

### 1.1 Introduction to the Research

Within the aviation industry, globalisation has resulted in fierce competition (Borestein, 1992). Since 1992, the United States has signed more than 50 bilateral Open Skies Agreements (OSAs) with the main objective of promoting an international aviation system based on competition among airlines with minimum Government regulation. The UK government's motivation to support these OSAs is the desire to facilitate the expansion of air-transport opportunities, making it possible for airlines to offer the travelling and shipping public a variety of service options at the lowest prices (Alejandro and Serebrisky, 2006). The positive effect of this agreement is not only reflected in the passenger population rise and financial gains but this liberation also lends towards increased international competition within the aviation sector. The effect of globalisation has created a dynamic market that fosters competition which demands higher levels of operational efficiency and supply chain maximisation. However, fluctuations in the global market resulting in difficulties with forecasting and an increased pressure for reduced inventories, is placing a critical focus across all industrial arms of the aviation industry including its service arm - the *Maintenance Repair and Overhaul* (MRO) sector (Andrew et al., 2008).

The Maintenance Repair and Overhaul (MRO) arm of the aviation industry is responsible for the restoration of an aircraft (product or system) to a state where it operates at its required level of performance (Luke T. Miller and Chan S. Park (2004). These restoration activities may arise as a result of either scheduled or unscheduled maintenance which are typified by partial or complete disassembly of the product; an inspection of the disassembled components, repair or replacement of faulty components, reassembly; and a functional test of the reassembled product. Whilst there are several processes that are common to conventional manufacturing environments, the process of MRO presents key challenges that make this

environment unique. Some of these key challenges characteristic of the MRO industry includes: *demand variability, complex and unpredictable (repair) flow paths, unpredictable supplier response times*, and even the *management of shared resources*. Whilst these issues are not limited to the MRO industry alone, they are more pronounced within the MRO context. For example, a decision on inventory levels is much more complex than the same decision in the manufacturing industry simply because the levels of inventory are much harder to predict in MRO context than they are within manufacturing context where a definitive order is much likely known ahead of schedule (Srinivasan *et al.*, 2014).

Also, globalisation has facilitated a trend of rapid fleet growth in the aviation industry which suggests that the MRO industry is poised significant growth, however, with even more intense competition. Boeing's 2014 Current Market Outlook projects the world's fleet will double over the next 20 years as 36,770 new planes take to the skies. Research published by the International Air Transport Association also predicts the MRO market will reach \$89 billion in 2023, up 47 percent from 2013. Thus, MRO organisations are not only seeking to increase their efficiency as concerned with internal operations but they also have to contend with new competitive forces and an increasingly demanding customer base.

Conversely, whilst the aircraft (or its component) is going through its MRO-required operations, the product itself is not generating any revenue. A conservative study presented by Boeing<sup>1</sup> showed suggest that the cost of an aircraft-on-ground (AOG) is about \$5,000 to \$10,000 per hour, with the actual cost of such one-to two-hour delays running as high as \$150, 000 depending on the airplane model and the airline. This makes the reduction in lead-time (or Turn-around-Time TAT) a key driver in the MRO offering.

Attempting to give customers what they want within acceptable timeframes sounds like a sensible business premise. Within the sphere of value creation, there is increased pressure on the MRO industry to seek ways in which to improve their productivity whilst meeting customer demands and yet remain profitable. With increased exposure to global competition, the imperative to mitigate the challenges becomes critical for business survival. At the core of a firm's survival is the firm's competitive position (Porter, 1985). Competition determines the

---

<sup>1</sup> [www.Boeing.com/commercial/global/opscenter.html](http://www.Boeing.com/commercial/global/opscenter.html).

appropriateness of the firm's activities that can contribute to its performance to include *innovation, a cohesive culture and good implementation.*

Although there are many initiatives to improve enterprise-wide productivity (Lewis, 2000), Lean approach has increasingly emerged as a notable initiative adopted by the MRO industry in mitigating its challenges (Srinivasan et al., 2014). The adoption of Lean within aviation MRO contexts is largely predicated on its remarkable success within the automotive manufacturing industry especially when tasked with similar challenges as currently witnessed by the aviation industry (Almeida, 2005). Kilpatrick (1997) explained that Lean manufacturing facilities were able to increase their capacity, quality, and productivity while simultaneously reducing inventory and order lead time(s). Baines et al., (2006) reaffirms the position that the correct application of Lean principles represents an opportunity for improvements in competitiveness within conventional service context. Thus, it is no surprise that Lean has transcended beyond the manufacturing environments into other environments like the aviation MRO industry. Indeed, a few MRO organisations have also attributed some of their successes to the adoption of Lean approaches.

From the abundance of literature advocating the applications of Lean to commendable successes in conventional 'manufacturing' and 'service' contexts, it has been determined that the application of Lean is industry specific (Crute et al., 2003). Literature review also suggests that while the application of Lean may lead to positive outcomes, these outcomes do not necessarily translate into competitive advantage (Lewis, 2000). This thus raises a few questions as to the suitability, the focus, strategy of implementation and expectations of Lean in the MRO environment. Conversely, although there is ample literature with regards to Lean in the aviation industry facilitated by MIT Lean Advance Initiative (LAI) (from which Lean Aerospace Initiative was birth running through 1993-2012), there is still a relative paucity in primary literature concerning Lean in the MRO sector. Notwithstanding, the available literature do address some of the operational issues of implementing Lean in MRO context.

Conversely, the predominant focus of Lean application is centred on the application of Lean tools and techniques. Whilst this can result in significant positive results, it represents a part of what constitutes for enhancing competitive positioning (Porter, 1985). For example, although a critical point in the Lean thinking is the focus on value; value creation is often interpreted as equal to cost reduction which represents a common yet critical shortcoming of

the understanding of Lean (Hines, 2004). Thus, applying Lean tools and techniques solely for the purposes of cost reduction may result in significant benefits; however, these benefits may not translate into competitive advantage. Although competitive advantage grows fundamentally out of the value a firm is able to create for their buyer that exceeds the firm's cost of creating it (Porter, 1985), the MRO challenge is not limited to the operational issues alone but equally the increasingly intensity of global competition. Thus, the main focus of this research will be to investigate and present how Lean can be realised in the MRO context to enhance competitive advantage.

A study carried out by Ma (1999) led to the conclusion that attaining and sustaining competitive advantage exceeds beyond a collection of product-market activities (Porter, 1980) or as a bundle of resources (Barney, 1997). However, the two fundamental questions with regards to attaining and maintaining competitive advantage posed by Porter (1985) remain valid. The first question relates to the attractiveness of the industry for long-term profitability (and the factors that determine them) as not all industries offer equal opportunities for sustained profitability. The second question relates to the relative competitive position of the organisation within the said industry. While this focus of this study is not to present a strategy for competitive advantage, it will seek to present the role of Lean in enhancing competitive advantage within the aviation MRO industry. As such, the layout of this thesis adopts a symmetry that seeks to first understand the state-of-the-art of Lean within the aviation MRO industry (“...attractiveness of the industry...”) and then, the status of MRO Lean engagements (“...relative position of the organisation...”). This study presented in this thesis will show using gaps identified within the literature (Chapter 2) and in practice (Chapter 4), and then use this premise to develop the role of Lean in enhancing competitive advantage within the aviation MRO context. This thesis sets out the issues, and documents a research programme through which Lean can be successfully realised in the MRO sector. This research contributes to the sparse knowledge of Lean within this context and also equips organisations with an understanding that will help to inform and guide their Lean journey.

## 1.2 Overview of Research Aim and Objectives

This section presents an overview of the research aim and objectives that are fully developed later in later sections of this thesis. The aim of this research, as presented in (Section 3.2), is:

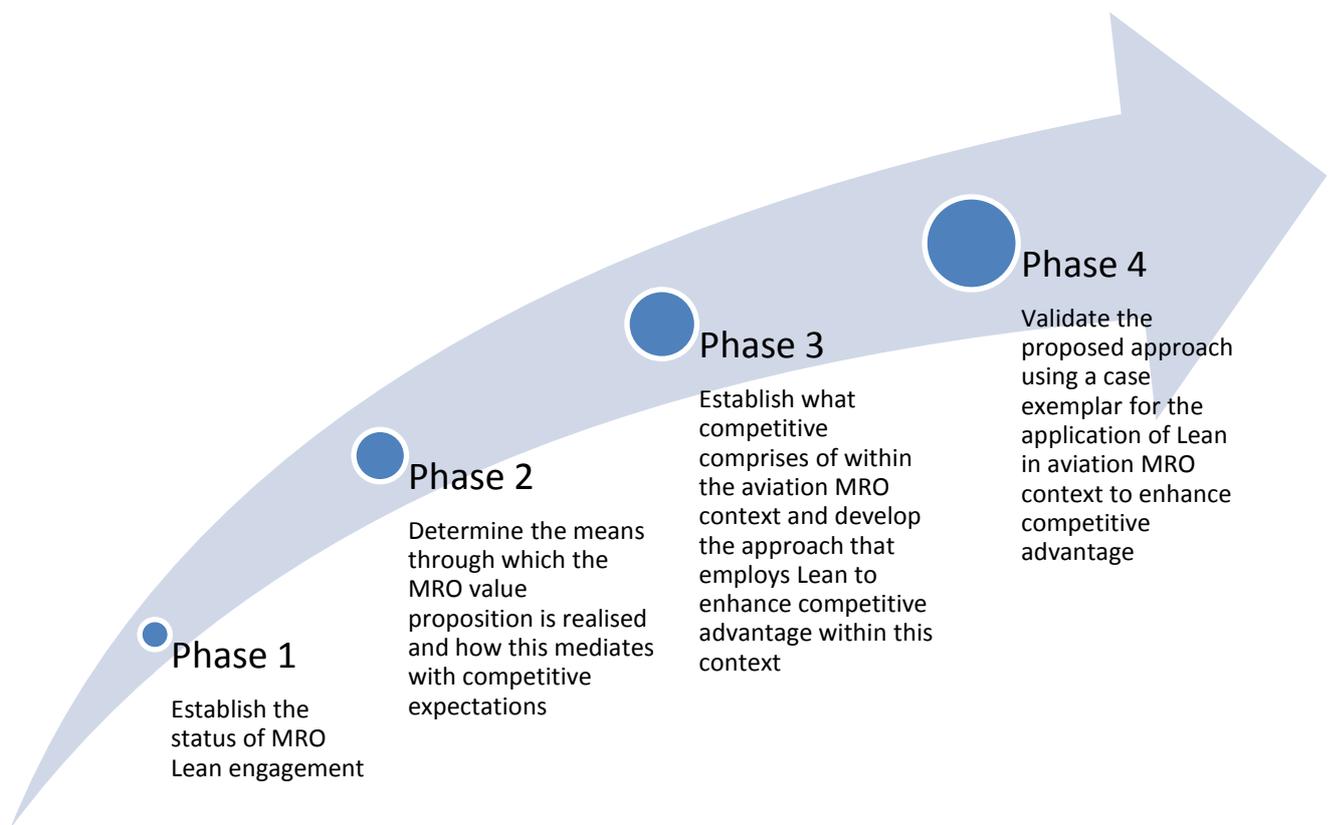
*Understand how the value proposition of the MRO is realised and present a comprehensive approach as to how Lean can be deployed within this context to enhance competitive advantage. This research will also enable the assessment of performance gaps and aid the user in aligning strategy with the expectation of Lean to achieving competitive advantage.*

To achieve the research aim the following research objectives were set:

1. Establish the status of MRO Lean engagements through Literature review and empirical study (especially with regard to the *interpretation, motivation, focus, extent, strategy* of implementation, *critical success factors* and *inhibitors* of Lean application).
2. Determine the means through which the MRO value proposition is realised and identify how competitive expectations are mediated through this means.
3. Establish what competitiveness within MRO context comprises of and develop the approach that employs Lean application to enhance competitive advantage.
4. Validate the proposed approach of Lean application to enhance competitive advantage using a case exemplar.

## 1.3 Overview of the Research Programme

The research aim and objectives led to a five phase research programme which is summarised in Figure 1.1.



**Figure 1.1: Overview of Research Programme**

The state-of-the-art literature review helped to provide the primary basis of the prevalent relationship between Lean and the MRO industry. This literature review particularly explored the focus, interpretation and strategy of Lean adoption within the industry. However, the paucity in primary literature specific to the MRO context provided the basis for actual industrial engagements to first verify the findings from the literature review and secondly, to gain more insight into the MRO value proposition is realised. Synthesis of the gaps identified from literature review and the industrial engagements form the scope within this research is focused.

**Phase 1** is aimed at satisfying objective one of this research in that it seeks to explore and understand the status of MRO Lean engagements. This was achieved via a literature review to establish the state-of-the-art of Lean within the aviation MRO industry as presented in chapter 2. The objective is to identify from literature how is Lean interpreted within the aviation MRO industry and to what extent has Lean been adopted within the aviation

industry. It also explores the prevalent strategies employed in the adoption of Lean within aviation MRO context, the inhibitors and enablers to the adoption of Lean. It concludes with an insight into the strengths and weakness of existing literature. The literature review provides the primary boundary in scoping the areas where further study is needed. The scope of this research is limited to the gaps identified.

Further to the literature review, actual industry engagement was also carried out to substantiate the status of aviation MRO Lean engagements. An empirical study facilitated by an industry-wide survey was used to engage industry practitioners to not only better define the state-of-the-art of Lean in the aviation MRO context, but to also ascertain the influence of Lean in helping business realise their value proposition and business success. The outcome of this study is presented in chapter 4 and satisfies objective one of this research. Based on the outcome of **Phase 1**, it became necessary to understand how the MRO realises its value proposition. This is because it was noted that the prevalent application of Lean was predominantly directed towards the shopfloor operations (operational context). As such, it was necessary to understand the means through which MRO value propositions are realised. This led to the delineation of a framework (*value delivery system*) which brings together into composite whole all various the elements through which the MRO value proposition is realised. It is within this context that Lean is to be deployed to enhance competitive advantage. All of these outcomes satisfies objective 2 and are realised in **Phase 2** (chapter 5) of this research programme.

Based on the outcome of the Phases 1- and 2, **Phase 3** sought to understand what competitiveness within the MRO industry comprised off. The aim of this research is not necessarily the application of Lean within the aviation MRO industry, but particularly how Lean can be applied to achieve competitive advantage. Thus, it became necessary to profile what competitiveness within the aviation MRO industry comprised off and the role of Lean within this competitive context. Also contained in this phase is a review of the prevalent competitive routes and the MRO performance gaps along these routes are outlined. Presenting the how Lean can be deployed to achieve competitive advantage within competitive aviation MRO context satisfied objective three of this research. This is presented in chapter 6 of this thesis. The final phase of this research program (**Phase 4**), sought to use a case exemplar to validate the outcome of this research satisfying objective four and completing the successful realisation of the research aim.

Although the findings from the research will still need to be observed over a long period of time, organisations that have embarked on a Lean implementation programme can use the position presented in this research to adjust or modify their Lean engagements to enhance their competitiveness. Furthermore, the understanding of how Lean can be successfully realised within the aviation MRO sector as presented in this research can also be submitted for further wider testing outside of the aviation MRO context.

#### 1.4 Overview of the Research Contribution

This section presents an overview of the research contribution. Full details are provided in the concluding chapter of this thesis (Chapter 8).

##### **The delineation of the MRO Value Delivery System**

With the increase in Lean adoption within the aviation MRO industry but with little published data as to ‘workings’ of Lean within this environment, the contribution to knowledge this research makes is first the validation of Lean’s suitability to enhance competitive advantage within the MRO context. In realising this outcome certain key discoveries were made. This included the clear delineation of the MRO Value Delivery System (VDS) which comprises all the various elements through which the MRO value proposition is realised. The clarity the VDS provide helps to highlight disjoint in expectations and the Lean efforts.

##### **Successful Lean Realisation engages all dimensions of value**

Whilst prevalent research into Lean in aviation MRO tend to focus on the operational aspect of Lean implementation, this research differs in that it presents the role of Lean across ALL the dimensions through which the MRO value proposition is realised - from the strategic intent to the economic and operational dimensions. The prevalent direction of Lean efforts towards the operational dimension as evidenced through literature review and the empirical study suggested more emphasis was placed on Lean tools and techniques as opposed to the thinking which should inform the use of the tools and techniques but also engages all dimension in value delivery.

##### **Lean application should be appropriated and consistent with the competitive route.**

The benefits resulting from Lean application does not automatically translate into competitive advantage. The general assumption that the application of Lean results in overall

effectiveness and inherently competitive advantage was investigated through the course of this research. As discovered from the case exemplar, one of the key instruments for competition is the *assets* owned by the organisation. *Assets* belong to the economic dimension of value delivery and prevalent application of Lean to the operational context may have only marginal effect on the competitive positioning of the organisation. As such, realising competitive advantage through Lean application requires that the focus of its application is consistent with the competitive aspirations of the organisations. Whilst Lean leads to overall effectiveness, its successes are to be correctly appropriated in order for it to enhance competitive advantage. Conversely, competitive advantage cannot be achieved without considering the competitive landscape of the industry. The competitive edge an organisation gains is achieved within the structural competitive analysis of the industry. An outcome of this research and a contribution to knowledge is the structural competitive analysis of the MRO industry.

All the deliverables from this research are achieved through a thorough process of in-depth investigation, development, and validation such that the gaps identified and focused on from the literature review and industry engagements were sufficiently addressed. The outcome of will also provide organisations with the roadmap that will inform their Lean efforts in enhancing their competitiveness. This research is supported by peer reviewed academic journal and conference papers, executive reports and global Lean summit presentations.

## 1.5 Overview of the Thesis Structure

This thesis is comprised of seven chapters, a summary of which is given here and is illustrated in Figure 1.2 at the end of this section. The summary of each chapter is as follows:

**Chapter 2** introduces a detailed literature review to establish the state-of-the-art of Lean in aviation MRO context. It presents the various illustrations of types, nature and illustrations of the MRO industry and the motivations for the adoption of Lean. The chapter concludes by presenting the gaps identified in literature that necessitates the need for this research.

**Chapter 3** describes the scope of the research problem and research methodology in addressing the problem. This chapter also contains the details of the research aim, objectives and the research programme developed to realising the research aim.

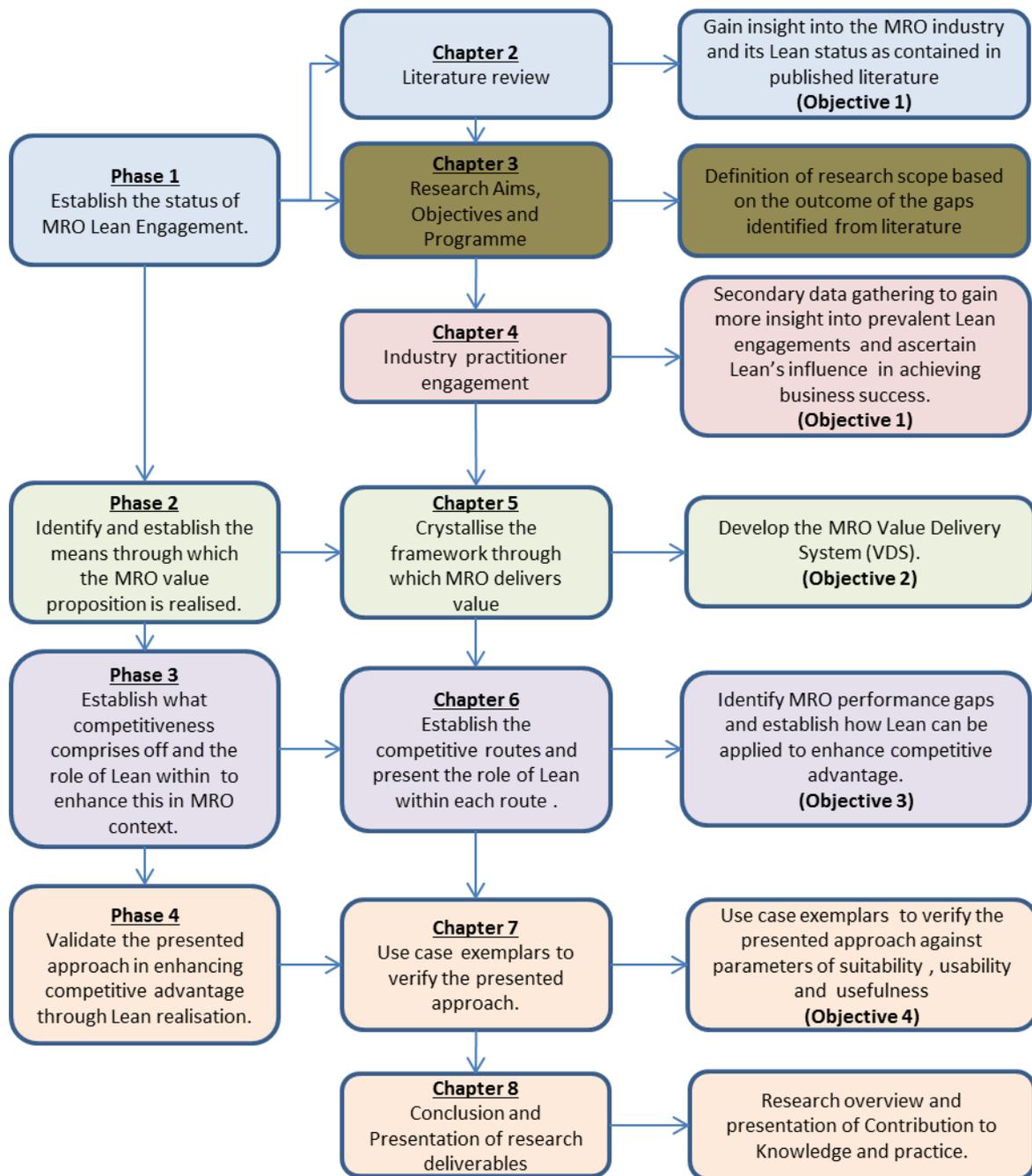
**Chapter 4** presents the empirical study carried out with a two-fold purpose: ascertain the findings from the literature review and to gain more insight both into *how* the MRO value proposition is realised and Lean's current influence. The empirical study was facilitated by means of an industry-wide survey. The survey design, execution, results and analysis of the data are presented in this chapter.

**Chapter 5** comprises of the development of a framework that brings together all the various element of how the MRO value proposition is achieved into a single whole known as the MRO Value Delivery System.

**Chapter 6** presents the structural analysis of the MRO industry and what competitiveness comprises of within aviation MRO context. The role of Lean in enhancing competitive advantage along the competitive routes is also elucidated on and the relationship between the forces of competition and the value delivery system is address.

**Chapter 7** describes the validation of the approach presented using a case exemplar – Lufthansa Technik Landing Gear Services (UK). The validation is carried out against parameters of *feasibility*, *usability* and *utility* via practitioner semi-structured interviews.

**Chapter 8** summarises the main deliverables of this research in relation to the aim and objectives and also highlights other observations that were discovered through the course of this research. It also summarises the contribution to knowledge and offers insight into where further investigation is required. The limitations of the research are also detailed as a basis for further research initiatives.



**Figure 1.2: Thesis Structure**

## 2. INDUSTRIAL CONTEXT: LEAN IN THE AVIATION MAINTENANCE REPAIR AND OVERHAUL INDUSTRY – LITERATURE REVIEW

This chapter explores literature to establish the state-of-the-art of Lean within the aviation MRO industry. It is broken into three parts. **Part 1** presents a detailed view of what MRO entails including the description (Section 2.1); its Objectives (Section 2.2) and the unique characteristics that distinct the MRO environment (Section 2.3). This section also highlights that various classification within the aviation MRO industry (Section 2.4).

**Part 2** explores what Lean entails by presenting the varying view of it and the principles that undergird it (Section 2.5). Based on the presented understanding of MRO and Lean (Section 2.6), the literature review research questions are developed (Section 2.7) and an overview of how the literature review is executed is presented (Section 2.8).

**Part 3** concludes this chapter by highlighting the findings in literature in relation to the research questions posed in Part 2. These findings are surmised to present the state-of-the-art of Lean within the aviation MRO context. The outcome of the literature review help to narrow the area of focus which this research seeks to address and also provides a strong indication as to the next step in the research process. Figure 2.1 provides an overview of this chapter in establishing the state-of-the-art-of Lean within aviation MRO context.

### Part 1: Overview of the MRO

- Description of the MRO industry.
- Objectives of the MRO industry.
- Unique Characteristics of the MRO.
- Classification of the MRO industry.

### Part 2: Lean in MRO

- Description of Lean and its principles.
- Further scoping and development of literature review questions.
- Overview of literature review approach and identification of sources.

### Part 3: Evaluation of literature and findings.

- Identification of findings from literature.
- Presentation of state-of-the-art of Lean in MRO as identified from literature.

**Figure 2.1: Overview in establishing the state-of-the-art of Lean in aviation MRO as presented in this chapter.**

## PART 1

### 2.1 A Description of the MRO Industry

Traditional perception of maintenance is usually to ‘fix’ broken items (Albert et al., 1999). However, taking such a narrow view limits the understanding of maintenance functions to reactive activities alone. Although aircraft maintenance checks are carried out periodically after specified time or usage, adopting an approach to maintenance that only focuses on the ‘*after the event*’ situations takes a limited view of MRO operations. This type of maintenance operation is often referred to as reactive maintenance, breakdown maintenance, or corrective maintenance (Albert et al., 1999).

Geraerds (1985) provides a more comprehensive approach towards maintenance and he suggests that “*All activities aimed at keeping an item in or restoring it to, the physical state considered necessary for the fulfilment of its production function*”. This approach to maintenance is more proactive in that it takes into account proactive tasks such as routine servicing, periodic inspection, preventive replacement, and condition-monitoring. Similarly, the Maintenance Engineering Society of Australia (MESA) adopts a similar perspective to the maintenance which suggests that maintenance is “*the engineering decisions and associated actions necessary and sufficient for the optimization of specified capability*”. “*Capability*” in this definition is the ability to perform a specific function within a range of performance levels that may relate to capacity, rate, quality and responsiveness (Tsang, 1998). Albert et al., (1999) thus suggest that the scope of maintenance management, therefore, should cover every stage in the life cycle of technical systems (plant, machinery, equipment and facilities): specification, acquisition, planning, operation, performance evaluation, improvement, replacement and disposal (Murray et al., 1996). When perceived in this wider context, the maintenance function could also be referred to as *physical asset management*.

Conversely, Al-kaabi et al., (2007) provide a similar assertion that the aviation MRO industry is primarily responsible for the retaining or restoring of aircraft parts in or to a state in which they can perform their required design function(s). Inclusive of the described periodic checks, MRO-type activities are principally the servicing, repair, modification, overhaul, inspection and determination of condition of the aircraft. These activities are a combination of all technical and corresponding administrative, managerial, supervisory and oversight activities tasks.

An example of a typical MRO organisation is ‘Hawker Pacific Aerospace’ (HPA). With two facilities in the UK and America, HPA specialises in the retaining and restoration of Landing Gears (aircraft/helicopters), Hydro-mechanical components, Wheels, Brakes and Braking systems, Flap Tracks and Carriages, Flight Controls, Constant Speed Drives, Integrated Drive Generators and even the distribution and sales of new and overhauled aerospace spares. Whatever the perspective, the MRO industry is the arm of the aviation industry is essentially responsible for the provision of a fully serviceable aircraft when required by the operator at affordable and reasonable cost with optimum quality.

There are two types of maintenance: *scheduled maintenance* and *unscheduled maintenance* (Kinnison, 2004). Scheduled maintenance is a preventive form of maintenance conducted at pre-set intervals to ensure that the aircraft is air-worthy. Scheduled maintenance and inspections consists of a battery of checks, depending on the number of flight hours elapsed: transit, 48 h, “A,” “B,” “C,” and “D” checks. The transit check is performed at each transit stop of the aircraft. 48 h checks are performed once every 48 h, and are more detailed than transit checks. The intervals for a Boeing 747–400 of “A”, “B”, “C” and “D” checks are 600, 1200, 5000 and 25,000 flight hours, respectively.

Unscheduled maintenance is needed in the event of a breakdown. Such maintenance actions are more definitive, requiring extensive testing, adjusting and often a replacement or overhaul of parts or subsystems (S.G. Lee et al., 2008).

## 2.2 The Objective of the MRO industry

In order to establish the state-of-the-art of Lean within the MRO industry, it is imperative to not only understand the main purpose of the industry, but to also understand its main objectives. In his book – Aviation Maintenance Management, he explains that the main objectives of the aviation MRO industry are:

1. To ensure or restore safety and reliability of the equipment.
2. To obtain the product and process information necessary to optimize maintenance when these inherent safety and reliability levels are not met.
3. To obtain the information necessary for component repair and tooling design for those items to be fully repaired or replaced during the overhaul process.

4. To accomplish these objectives within the required time limits and at a minimum total cost, including the costs of maintenance and the cost of residual failures (i.e. minimise the time an aircraft is taken out of service).

Whilst the MRO industry has become more sophisticated, its objectives have remained the same. This view is echoed by a research paper<sup>2</sup> published in 2016 by the United Kingdom's Department for Business Innovation and Skill which along with the objectives outlined by Kinnison (2004), adds that the objective of the MRO also includes:

5. Minimising unplanned or unscheduled maintenance, which would disrupt operations and create logistic and resource problems if such maintenance has to take place away from the operator's base.

The first objective of the MRO industry in ensuring safety and reliability of the equipment is realised via scheduled and unscheduled maintenance inputs. However, this objective can only be not be correctly realised with the aid of the key technical information which are contained in the Component Maintenance Manual (CMM) provided for each component. This CMM information is provided by the Original Equipment Manufacturers (OEM) such as Boeing. Maintenance information provided by the OEM include product structure information, fault detection and isolation tools, engineering drawings and even 3D viewing and mark-up tools, associative inspection and maintenance procedures. Furthermore, evaluation of maintenance tasks including the decision check whether to repair or to replace items is the common task of both the operator and the vendors. Detailed product engineering knowledge and procedures involved in any repair are necessary. Thus, OEM and MRO companies have to exchange information such as the component part numbers, references to standard Service Bulletins (SB), procedures, the repair schedule, inspection results, and the final agreed repair plan. The collaboration between OEMs and the MRO's not only helps to improve maintenance but also, such the feedback to the OEMs potentially improves the design of aircraft of the same or different model, thereby realizing the close loop of design for maintenance and service. In addition, (National) Aviation Authorities such as the Federal Aviation Authority (FAA - US)

---

<sup>2</sup> BIS Research Paper 275: UK industry Maintenance, Repair, Overhaul & Logistics industry analysis, 02/2016 (accessed July, 2016)

or European Aviation Safety Authority (EASA - Europe) also issue Airworthiness Directives (AD) which are mandatory instructions to the airline operators. Since most of these AD's are carried out by the MRO organisations, the exchange of information is not limited to the MRO and the OEM organisations but also to include the airline operators. The MRO's ability to access and use this information effectively satisfies the second and third objectives.

With airline operators seeking more cost-effective and reliable MRO vendors for their regular maintenance contracts, it is imperative that the MRO organisation is able to achieve the maintenance input operations within the required time and at the best quality. The ability of the MRO organisation to efficiently coordinate the maintenance task whilst effectively managing rising material costs, *siloed* processes, disparate systems and data overload within the required time limits is what objective four seeks to satisfy within required time limits.

### 2.3 Characteristics the MRO Industry.

This section seeks to outline the distinct characteristics of the MRO industry. The MRO industry is characterised by challenges such as high demand variability; uncertainty in the work-scope (and material requirements); unpredictability and complex flow paths and limited technical data (Srinivasan et al., 2014). Another unique characteristic of the MRO industry is what is referred to as *cannibalisation*, which refers to the removing of parts from one aircraft for use on another aircraft. Whilst these challenges are not limited to the MRO industry as they are indeed present in manufacturing context, they are more pronounced within the MRO context.

#### 2.3.1 Variability in Demand

Variability in demand is more pronounced in the MRO context as it is impossible to predict with utmost certainty exactly when an asset will require maintenance, repair or overhaul. Many MRO organisations however work with scheduled repair and overhaul of assets, where customer demand can be predicted more confidently even though the exact work content may not be known when the asset arrives for its MRO operations.

Again the demand-variability problem is not unique to the MRO industry alone. The classic job shop, which typically operates in high-variety low-volume environment, certainly must

be prepared to deal with high variation in demand. Even typical high-volume, low-variety manufacturing facility can receive order for special items that require immediate attention. In any case, these facilities face competition for shared resources.

### 2.3.2 Uncertainty in the work-scope

Unlike the typical manufacturing process, where the work content is determined by the product design well before production commences, work-content definition in the MRO process often takes place within the context of the on-going repair process. This on-the-spot-work-content- definition results in uncertain demand and schedules for the support shops as well which leads to unpredictable response times. These support shops often have to deal with unplanned repairs for which adequate tooling and work standards are often unavailable. Lacking adequate checklist of work instructions for such unanticipated repairs often results to trail-and-error approaches. Quite often, the support shops have to share their resources across multiples requests from different facilities, which often lead to priority changes and multitasking at the these resources.

### 2.3.3 Uncertainty in Supply

Uncertainties within the MRO enterprise propagate upward along the MRO supply chain, resulting in unpredictable response times from external suppliers as well. Faced within an uncertain demand, these suppliers are often unprepared to cater to customer demands, especially because they, in turn, have to order the raw materials or components, often from sources that require long lead times. The problem is aggravated because the demand for these products is typically low, which tend to make them economically infeasible for the supplier or the customer to maintain and inventory of these components.

No doubt it is practically impossible to keep every replaceable part in inventory, but having an asset eating for repair can be extremely cost prohibitive because there is a revenue loss for every moment the product is out of service.

### 2.3.4 Cannibalisation

A practice unique to MRO operations is cannibalisation. Cannibalisation is the practice of removing components of modules, either from an asset undergoing repair and using them on another asset perceived as needing it more urgently or from an asset inducted solely as a source of parts supply. Cannibalisation takes place because of the pressures to meet asset readiness. It also occurs because of shortcomings in the supply system.

Cannibalisation is fairly commonplace in MRO operations. Maintenance managers typically resort to this practice when faced with the lack of available spare parts and unpredictable lead times without considering the total cost of their decision. A lack of experience and insufficient training of maintenance personnel can also promote cannibalisation. A recent study of cannibalisation by the US Air Force and the Navy identified approximately 850,000 documented cases requiring 5.3 million additional maintenance hours, equivalent to 500 full-time aircraft maintenance personnel.

The case for cannibalisation arguably has merit for specific situations. Consider an asset with a defective Auxiliary Power Electronic Control Unit (APECU) that need to be replaced, with a replacement lead time of 12 weeks. Suppose that an identical asset in the facility with a functioning APECU is waiting modules that are unlikely to arrive in the next 12 weeks. This situation presents a strong case for cannibalisation. In theory both assets, the asset receiving the APECU and the asset donating the APECU, can be repaired and returned back to the customer sooner than otherwise would have been the case without the cannibalisation. The labour cost involved in the cannibalisation is relatively a small price to pay when compared with the benefits resulting from placing an expensive asset back in service.

From a system perspective, however, cannibalisation leads to a number of problems in the long run. A major and often overlooked problem is that cannibalisation often avoids highlighting problems in the supply chain that should be rectified. Furthermore, cannibalisation often goes unrecorded, creating more problems for the organisation, especially for the procurement functions.

#### 2.4 Classification of the MRO industry

Maintenance is can broadly classified as either *On-aircraft maintenance* or *Off-aircraft maintenance* (Kinnison, 2004). *On-aircraft maintenance* is performed on or in the aircraft itself and can be done with or without taking the taking the aircraft out of service. *Off-aircraft maintenance* entails the overhaul of systems removed from the aircraft which can be temporarily put out-of-service if substitute component systems are not deployed (Lee S.G., 2008).

All MRO operations are broadly categorised within these two basic classifications (*On/Off-aircraft maintenance*) depending on the type-function and requirement of the customer

(operator). This is because, regardless of the type of MRO input required, it should be tailored to suit the individual requirement of the operator. The UK department of Business Innovation and Skill<sup>3</sup> categorise the operators into the following groups:

- **Airlines, Air Transport and Cargo Operators:** Operators within this classification usually have the highest level of product utilisation and as such, tend to require relatively more MRO input. Also, it is usual for operators within this category to have aircrafts on lease which requires that aircrafts are maintained to a high standard according to the requirements of the lessor. The type of MRO input include both on-aircraft maintenance (e.g. Line Maintenance) which could take place at remote destination and off-aircraft maintenance which will usually require that the aircraft is flown back to the operator's main base form where the MRO input will be expedited. Thus, MRO organisations (and their supply chains) should be acutely aware of the operator's requirement in order to provide the necessary support. Subsequently, this sector represents the largest revenue generators to the MRO industry especially as operators within this group tend to have larger fleets of aircrafts.
- **Corporate, VIP or Business Aviation Operators:** Operators within this category generally have a smaller fleet size as they are usually owned by companies, or high net worth individuals who are keener on the availability of their aircraft to fly to diverse destinations at short notice. These aircraft are typically owned by companies or high net worth individuals. This sector operates expensive and the most sophisticated aircraft, systems and engines and while they do not fly as much as the airlines the MRO input is similar necessitated by time and or usage.
- **Helicopter Operators:** Operators within this category tend to have a relatively smaller area of operation such as the North Sea. Since this type of aviation products are not capable of flying the long distances, the type of MRO input required is usually on-site usually at the operator's main base.

---

<sup>3</sup> BIS Research Paper 275: UK industry Maintenance, Repair, Overhaul & Logistics industry analysis, 02/2016 (accessed July, 2016)

- **Military Aircraft Operators:** Operators within this category require high availability and reliability of their products (ranging from aircrafts, helicopters to even Unmanned Aircraft Vehicles, UAVs). They generally operate their equipment in harsh and hostile environments and as such, the MRO input is carried out also on-site and by specially approved bases.
- **Special Mission Operators:** This category of operators includes operators like air ambulance, police helicopters, research aircraft etc. Although this is a relatively small customer base, the MRO input is tailored to suit the specific requirement of the operator.
- **General Aviation Operators:** Operators in this category include leisure operators and training schools of privately owned light aircrafts. Whilst this revenue from this sector is not as significant as all the other sectors, the MRO input required are usually carried out on-site at the operators main base.

Furthermore, it is also important to note that not all maintenance facilities are classed as MRO organisations. What identifies an MRO organisation is determined by an approval known as the ‘Part 145 Approval’ (or its equivalent provided by the national aviation authority in which an aircraft is registered). In the UK, both the Civil Aviation Authority under the authority of the European Aviation Safety Agency (EASA) and the MoD Military Aviation Authority (MAA) approve Part 145 maintenance organisations to carry out designated MRO input on UK civil and military registered aircraft respectively<sup>4</sup>. Within the Part 145 Approval is also a Class and Rating structure which further categorises MRO operations based on capabilities and specialities. The approval Class is subject to the major subsystem of the aircraft which are:

- Aircraft (Airframe)
- Engines
- Components
- Specialised (Non Destructive Testing or Evaluation, welding etc.)

---

<sup>4</sup> BIS Research Paper 275: UK industry Maintenance, Repair, Overhaul & Logistics industry analysis, 02/2016 (accessed July, 2016)

Within each Class structure is also a Rating system which further details specific items that the MRO organisation is approved to support. For example, the Rating may include specific engine models or aircraft types that the MRO organisation is approved to support such as a Rating B1 Turbine Engines and a Rating A1 refers to Aeroplanes whose take-off weight or mass exceeds 5,700 kg.

With this understanding of the type of MRO input (*on-aircraft* and *off-aircraft*); the categorisation of the customer (operators); and the capability of the MRO organisation (Part 145 Approval), the following section of this chapter present the classification of the MRO based on “*what*” type of service (type-function) and “*who*” provides the service (structure of the organisation).

#### 2.4.1 MRO categorisation based on type-function

The MRO-type functions can be broadly categorised into the following: Line Maintenance; Hanger (Heavy) Maintenance; Engine Overhaul; Component Overhaul; Avionics and Retrofits and Conversions. Due to the nature and type of overhaul required, MRO firms are usually *specialised* and *specific* in the type of overhaul they perform. The specialist roles by which MRO organisations can be classified are briefly described below and are illustrated in Table 2.1.

- **Line Maintenance:** This function involves the routine maintenance of the aircraft. MRO organisations within this category are responsible for the frequent inspection of the aircraft to ensure its safe in-service use. Line maintenance entails work associated with, for example, transit, 48-h, “A,” and “B” checks. Examples of such inspections include checking the brakes, oil levels, the condition of cargo door seals and the wing surfaces for obvious damage or oil leakage<sup>5</sup> (FAA). MRO organisations within this category can also carry out minor repairs as advised/required by OEM.
- **Hanger (Heavy) Maintenance Visit:** Hanger Maintenance entails scheduled checks, modifications of the aircraft or aircraft systems by an airworthiness directive or

---

<sup>5</sup> Federal Aviation Administration (FAA). p.8-15. FAA-H-8083-30.

[http://www.faa.gov/library/manuals/aircraft/amt\\_handbook/media/FAA-8083-30\\_Ch08.pdf](http://www.faa.gov/library/manuals/aircraft/amt_handbook/media/FAA-8083-30_Ch08.pdf) (accessed January, 2010).

engineering order, special inspections mandated by the airline, the FAA or other regulations, painting of the aircraft and aircraft interior modifications. During hangar maintenance, the aircraft is out-of-service (Lee S.G., 2008). This usually involves the disassembly of major components of the aircraft for detailed inspection and repairs.

- **Engine Overhaul:** This ranges from routine service checks to local repairs and complete overhaul of the engines. It is potentially the largest sector within this industry and depending on the nature of the repair carried out, this can either be done whilst the engine is still mounted on the aircraft (on-wing services) or at an approved maintenance facility (off-wing). The Auxiliary Power Units - APU (which provide electrical power and compressed air to the aircraft whilst on the ground without the need of using the main engines or an external ground power unit) also fall within this category.
- **Component Overhaul:** This usually involves the overhaul of all other parts not categorised under the heavy maintenance category. These range from Landing Gear to Fuselage overhauls. All tasks exceeding the advised remit of Line maintenance will usually require more detailed investigation and work input rendering the component unserviceable until the required maintenance operation(s) have been correctly carried out.
- **Avionics:** MRO organisations within this category specialise mainly in the overhaul of the aircraft avionics and associated components. Avionics are typically the various electronic components and systems developed under various types of disciplines (both military and commercial) into a cohesive working master system that would increase the overall efficiency of the aircraft.
- **Retro-fits and Conversions:** This sector is responsible for the major and minor design retro-fits and the conversion of passenger aircrafts to freighter aircrafts.

Although all of the described functions are different in operation, there are huge similarities (in principle) in the manner in which these services and operations are carried out. However, an understanding of the different types of MRO organisation will facilitate a better understanding in the adoption of Lean within the MRO industry.

Sector	Examples
<b>Line Maintenance</b>	Scandinavian Aircraft Maintenance (Norway); SIA Engineering (Singapore)
<b>Hanger (Heavy) Maintenance Visit</b>	AAR Corporation (Global, HQ Illinois, USA); SR Technics (Global HQ Switzerland, Zurich); ST Aerospace (Global, HQ Singapore); GE (HQ US)
<b>Engine Overhaul</b>	Lufthansa Technique (Hamburg, Germany); Rolls Royce (HQ UK).
<b>Component Overhaul</b>	Hawker Pacific Aerospace (UK/USA); APPH (UK); Ameco (China)
<b>Avionics</b>	Honeywell (Global); Selex Galileo Global (Italy/UK)
<b>Major Modification/Retrofits/ Conversion</b>	Aeronautical Engineers (USA); Airbus (Dresden, Germany), Haeco (Honk Kong, China)

**Table 2.1: MRO-type Functions and Logistics**

#### 2.4.2 MRO categorisation based on ownership and organisational Structure

Using the organisational structure as the criteria for categorisation, MRO organisations can be broadly grouped into two – *independent/third-party* MRO organisations and *airline operated/owned* MRO organisations (Cohen, 2006; Al-Kaabi, (2007); Michaels, 2007). The MRO industry has evolved over the years from when the majority of MRO activities were purely carried out by *airline operated/owned* MRO organisation (Al-Kaabi, 2007). In some cases, approval was given by the OEM to carry out these MRO type operations for components still under a valid warranty. The eventual parts and labour cost of any such repair or overhaul was then invoiced to the OEM (Lorell et al., 2000). However, following deregulation in the US in 1978, many airlines just entering the industry did not have existing MRO facilities or spare parts inventory(ies) to support their fleet (Almeida, 2005). The growth of these new low cost carriers encouraged the entry of *independent* MRO providers who offered relatively low-cost services ranging from line maintenance to inventory control. In an effort to cut costs, several of the established airlines, such as British Airways and American Airlines, began outsourcing more of their MRO activities to *independent* MRO organisations. This allowed managers to leverage resources and capabilities by concentrating on core competencies that create value for the airlines’ customers, with non-value added activities being outsourced (Al-Kaabi, 2007).

The cost in establishing an airline MRO is considered to be relatively high and *smaller* and newer airline carriers may not be able to commit to such cost. Low fare carriers with traditionally streamlined business models have avoided strategies adopted by major airlines of investing in large maintenance stations, but instead, have opted to outsource most MRO-type operations (especially heavy duty maintenance) to *independent/third party* MRO providers (Cohen, 2006; Michaels, 2007; Almeida' 2005; Heikkila, 2002). In contrast, *bigger* airline operators prefer to retain a presence in this field [8]. The advantage of this choice is that Full Service Carriers (FSC *also sometimes referred to as Legacy carriers*) can compensate for the varying passenger volumes by offering MRO type services to other airlines (Kilpi et al., 2004).

An example of an *independent/third-party* MRO organisation is AAR Corporation. AAR is the second largest independent provider of MRO services in North America and its operations range from aircraft and engine support to engineering, logistics and precision fabrication capabilities. AAR provides both stand-alone services and customised, integrated solutions offered through unique combinations of diverse products and services. Conversely, Lufthansa has over the years boosted its maintenance arm (Lufthansa Technik) and has seen a steady growth in its MRO capabilities. Similarly, the joint venture between Air France Industries and KLM Engineering & Maintenance has also experienced tremendous growth with regards to its MRO capabilities hence retaining as much of the maintenance functions for its fleet in-house as expected of a typical *airline operated/owned* MRO organisation.

#### 2.4.3 MRO industry described within Product-Centric Service terms

Nowadays, there is a growing trend for OEMs to adopt '*servitized*' business models and thus offer an array of support packages directly to the customer. Servitization is traditionally described as the shift by manufacturers from selling the product alone with a few essential services to using services as a basis for competitive strategy (Baines et al., 2007). With more value generated with increased *interaction* with the customer (Wise and Baumgartner, 1999), OEMs are offering packages that extend beyond the warranty of purchased products to include a complete service package that deals with the maintenance, servicing and spare-part replacement over a fixed time period. These support packages range from Bundled Asset Management Programmes (BAMP) to Integrated Customer Support (ICS) (Michaels, 2007). An example of such support or service offering includes '**TotalCare**' offered by Rolls

Royce<sup>6</sup> and ‘GoldCare’ offered by Boeing<sup>7</sup>. These packages essentially integrate engineering and planning services at a predictable and competitive cost with enhanced economies of scale. With packages such as these, OEMs are beginning to take up major stakes in the maintenance budget of airlines thus adding to the paradigm shift in the way maintenance is been viewed within the aviation industry. This also supports the proposition that more interest is not only given to *how* the maintenance service is carried out but *who* carries this out.

Similarly, there is a general trend of MROs owning assets that are used to support airline operators whilst their product is being overhauled. This suggests that typical MRO operations extend beyond what happens in the factory to the direct interaction with the customer also extending the scope of the application of Lean. Furthermore, due to the nature of these asset management programmes, OEMs have restructured their capabilities and MRO requirements resulting in a business operation that is slightly different from the traditional MRO organisation. This presents the new opportunities to explore the application of Lean philosophy beyond the maintenance facilities to the interactions with the customer and indeed the global market space.

---

<sup>6</sup> Rolls-Royce.com (2004). Delivering value through services for the 21st century, available from (<http://www1.rolls-royce.com/service/downloads/service.pdf> (accessed March, 2009).

<sup>7</sup> Boeing.com (2006). Asset Values and the Aircraft Maintenance Revolution, e-newsletter, Issue 5, available at [http://www.boeing.com/commercial/P2P/pdf/p2p\\_newsletter\\_09-06.pdf](http://www.boeing.com/commercial/P2P/pdf/p2p_newsletter_09-06.pdf) (accessed March, 2009).

## PART 2 – Lean in MRO

### 2.5 Description of ‘Lean’

Contrary to popular perception, many characteristics of Lean techniques were first recorded at the Ford production plants in the 1920’s as documented by Henry Ford himself in his books ‘*My life and work*’ (1922) and ‘*Today and tomorrow*’ (1926). Ford demonstrated the need to focus on the activities that are of service to the customer and wherever possible reduce the waste of material time and motion. However, the term ‘Lean’ itself was popularised by Womack and Jones (1996) after careful consideration of the Toyota production operation. This study was sponsored by the International Motor Vehicle Program (IMVP) as part of a worldwide auto manufacturing benchmarking study. In 1996, Womack and Jones published the book ‘*The machine that changed the world*’ (Womack et al., 1996). This book helped to demystify the Japanese auto manufacturing techniques initially referred to as the Toyota Production System (TPS) showing its manufacturing superiority.

The central theme of Lean as described by Womack and Jones (1996) is the elimination of ‘waste’ (*muda*<sup>8</sup>) in order to improve productivity and enhance overall customer value. Baines *et al.* (2006) suggested that the philosophical approach to Lean thinking is ‘*multidimensional*’ in the sense that it involves the entire organisation in every function and encompasses a ‘*wide variety of management practices including just-in-time (JIT), quality systems, work teams, cellular manufacturing, supplier management etc. in an integrated system*’. Based on this definition, he concluded that it is no co-incidence that the Japanese companies who approach Lean implementation in this manner record greater successes than their western counterparts. It is however important to point out that modern references to Lean *thinking* have variations in content and perspective (Hines, 2004). The disparity ranges from the Japanese industries that tend to focus on Lean ‘*philosophy*’ and ‘*culture*’ compared with their western counterparts who tend to put more emphasis on the ‘*tools and techniques*’ of Lean. The disparity in the perspective of Lean into these two divides has led to discussions of which one is more accurate. Literature study also shows that the benefits of Lean cannot be realised simply by adopting a few tools and techniques. Intriguingly, most western manufacturers are focusing their Lean initiatives on operations with few attempts to adopt Lean as a culture. Whatever the perspective, neither of the positions is more correct than the other, since Lean exists at all levels both practical and theoretical (Pettersson, 2009). The aim of Lean however,

---

<sup>8</sup> Muda – Japanese term for *waste*

is to reduce all forms of waste (*'muda'*) as identified by Ohno (1988). Bearing this in mind, this thesis will be careful in distinguishing between both perspectives *'Lean thinking'* and *'Lean principles'* in areas where their understanding and intent is crucial. However, in areas where their intent and understanding is not crucial and to reflect popular usage, this thesis will refer to both perspectives simply as *'Lean'*.

The express approval and success record of Lean in the automotive industry has signalled other industrial sectors to awaken to the immense benefits that this philosophy has to offer (Melton, 2005). Within the aviation industry for example, some MRO firms have been able to cut TAT dramatically by employing tools that relate to Lean principles. The most important factors in an airline's selection of an MRO supplier are typically quality, TAT and price, in that order. However, special circumstances can shift customer priorities which could mean that the priority changes. For example, an airline could have a situation where there are temporarily more aircrafts than needed to deliver its schedule thus giving TAT lower priority. But for a fleet sized right for its network, a short TAT is key to minimising total maintenance costs. The progress in reducing TAT should prove to be a strong competitive advantage (Canaday, 2009).

Conversely, in an environment where quality and safety standards are tightly regulated, there is the concern as to whether all the principles of Lean philosophy are viable in this context. Since the main objective of the MRO industry is to restore the aircraft back to a state where it can safely perform its design functions, a process which can be loosely referred to as *'re-manufacturing'* (Almeida, 2005; Al-Kaabi, 2007), there is the assumption that all of the principles of Lean can be implemented within this context. However, there is not enough proof in current literature to confirm this assumption. Hence, the study described in this thesis is targeted to investigate the extent of the adoption of Lean principles and its philosophy within the aviation industry particularly within the MRO sector.

Womack and Jones (1996) suggest that there are 5 major principles of Lean. These principles are:

1. *Specify value from the perspective of the customer:* Many organisations tend to give the customers what is convenient for them, or what is deemed economical for the customer and not necessarily what the customer wants. For example, a batch-and-queue airline travel system usually involves long trips to the airport to enable big

batch flights which start off far away from the customer's preferred starting point and take you via hubs (or places you did not intend to visit) with numerous delays along the way. The customer's value in this instance has not been the driving factor in this system. However, this example reveals that in order to specify value from the customer's perspective, you have to first know who the various *customers* are. The *customer* not only refers to the final end-user but also, the next process (or next company) along the supply chain (or touch point).

2. *Identify the value stream:* This refers to sequence of process involved within the production system (or supply chain) in delivering value to the (end) customer. It involves all the several process (touch points) from the start of the process (raw material) to the final customer (or product). Since the concept of Lean is founded on the idea of waste elimination, it therefore follows that the whole supply chain is examined to find out where the waste exists so that they can be addressed.
3. *Flow:* This principle is centred on the flow of value across the production system (supply chain). It is important to point out that all operations within a production system can be largely grouped into two: *value-adding* operations and *non-value* adding operations. The focus of Lean is to eliminated the non-value adding operations and allow for the *flow* of the *value*. Features within this principle may involve the re-design of the production system to include changeover reduction, multi-skilled operators, and supplier partnerships as suitable.
4. *Pull:* Having setup the business framework for the flow of value, only produce as much as needed. This means that production is directly proportional to customer demand and avoids the temptation to overproduce. This the principle of *pull* is not limited to the organisation alone but also to all supplier partnership within the production system which thus mean that the end-customer demands are shared right along the supply chain of the production system. Although, the *pull* principle is not strictly applicable in all industrial sectors especially where instant response is required (an apple tree will not grow overnight in order to provide the customer with apple juice), but the *pull* approach can be applied for several stages from the end-customer which each extension reducing forecast uncertainty.

5. *Perfection*: Having established a production system that has addressed all the preceding 4 principles, the next stage is to standardise and perfect the production system. Perfection is not a destination but a journey and this will involve continuous iterative application of the preceding principles. This is will that the production system is able to provide exactly what the customer wants, exactly when they need it at a fair price and with minimum waste.

## 2.6 *Lean thinking within the MRO industry*

Whilst the principles of Lean remain the same regardless of the context of application Manufacturing context (akin to high-volume production) or MRO context (more akin with low-volume production); it is important to point out that there is a difference in Lean thinking between the two contexts. A key distinction that undergirds this thinking is the difference between “**Process Variation**” and “**Work-scope Variation**”. Process variation refers to the deviation from the ideal (as identified through the principles of Lean earlier explained) and it is indicative of a process failing or inadequacies of the process. Both MRO and Manufacturing context experience Process Variation with examples ranging from equipment downtime to quality defects in the products to also excessive delays in processing (Srinivasan et al., 2014). The goal in both cases is to eliminate any process variation so as to make the time required to do any particular operation more predictable. Thus, successful Lean realisation within the manufacturing context is usually achieved by having items move through workstations in manner akin to parts flowing in a moving assembly line, sequenced according to the assembly steps. The tools, parts and workers are stationed where they are needed, and parts are fabricated or assembled as they flow down the line. The advantage of this is that variation is more readily apparent and significant delays at any point in the process could potentially stop the entire operation. This practice makes more visible where the root-cause of the problem is and efforts can be appropriately directed to address the problem(s).

However, within MRO, what is more prevalent is a variation in **work-scope**. Work-scope variation refers to the stochastic processing requirements of the different elements that make up the assembled product. For example, different items may have different work requirements, and flow paths and as such, it is not desirable to stop the flow of all the items

just because one particular item requires additional work (Srinivasan et al., 2014). Thus, Lean thinking within MRO context requires a different strategy in addressing work-scope variation which is inherent of MRO operations. Although an assembly-line approach could also be adopted within MRO context, its success is hugely dependent on having a strategy to effectively address the work-scope variations. Examples of solutions that would more readily be apparent within MRO context includes having the disassembly and reassembly operations happening on stationary stands and waste in movement of parts, tools and motion of people can be minimised by having Standard Operating Practices/Procedures (SOP) for the order in which work is done.

The combination of both process variation and work-scope variation makes the nature of MRO operations different. Although MRO input is necessitated by usage or time, the actual work scope is not fully known until full investigation (disassembly and test) has been carried out albeit constrained by the TAT (turn-around-time) already promised to the customer. There is therefore a high degree of uncertainty incorporated into MRO operations. The ideal however will be to be able to identify most of the non-routine requirements as early as possible within the planned time of the check, so that these exceptions can be re-scheduled effectively to meet TAT target. In order to achieve this, increased level of collaboration is required amongst stakeholders all the stakeholders to define optimal work scopes based on insights about repair issues, configuration and even On-wing repairs. Looking at data patterns, stakeholders in the process can ask: What is the best approach to realise their maintenance operations? Which parts are worth repairing and which are not? Are some parts not repairable at all? Should we consider Part Manufacture Authority (PMA)? Should the maintenance inputs be done *on-condition* or should they be done on the basis of the usage and time alone (Michael R., 2012).

Distinguishing between process variation and work-scope variation helps to developing appropriate solutions to mitigate the challenges facing the MRO industry. The inability to effectively address these challenges results in relatively higher production cost. Thus, the ubiquitous adoption of Lean within MRO context should facilitate a thorough review first of the diagnosis of the problem and the measure that have been applied to address these problems. A publication by Price water Coopers (2010) suggests a maturity profile that describes organisations that have successfully carried out this review. They suggest that organisations of such calibre are able to operate more programmatically and capture savings

opportunities quickly. The distinct phases are range from a purely reactive mode to one that is predictive and more cost-effective—by focusing on the four dimensions of an MRO performance model. These four phases are (PwC, 2010):

- *Crisis maintenance*: This is the first phase (*inert*) in which almost all MRO organisations find themselves in and referred to as the reactive mode. Businesses that mainly operate within this phase fail to consistently realize cost savings or productivity gains.
- *Just-in-time maintenance*: Organisations who have through Lean initiatives transitioned into this phase are capable of using just-in-time approaches to benefit from lower costs, reduced inventory and improved working capital. Even with urgent requests (AOG), their enhanced processes and systems are robust enough to deal with these requirements and still meet turnaround time commitments.
- *Planned maintenance*: This phase involves a more pragmatic approach towards MRO operations. This phase is fostered by increased collaboration between the MRO organisation and the airline operators where relationships are in place for more periodic MRO inputs. For example, a business may have contractual relationships in place to perform a specific number of repairs each month. Or it may have a field service response profile in which it has committed to a certain percentage of uptime across the fleet at all times.
- *Predictive maintenance*. This final phase evolves from the successful transition of the earlier three phases where a thorough understanding of the aircraft has been achieved which can now inform a better maintenance programme.

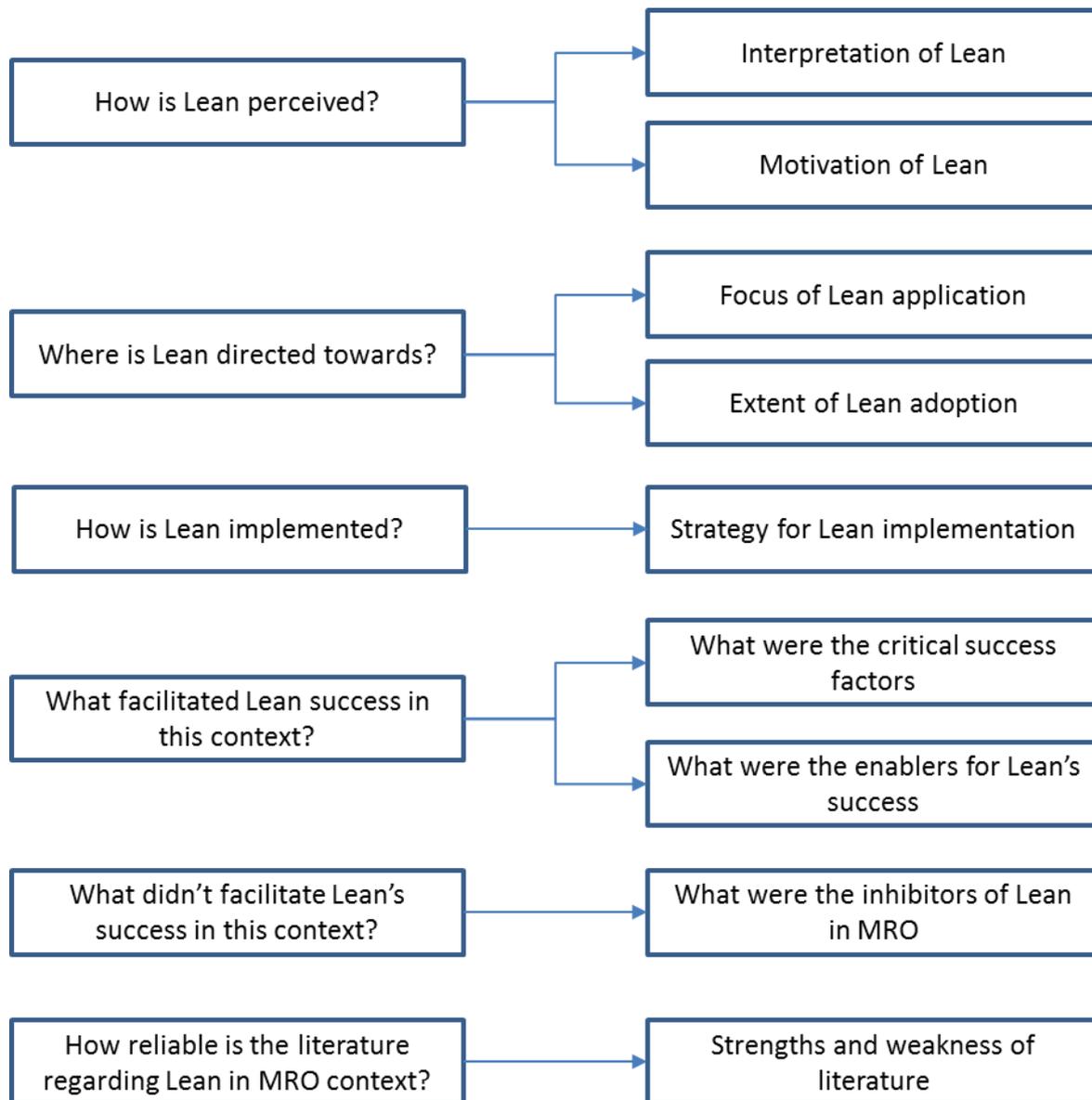
These four phases can be used to map the maturity of any Lean Programme within the aviation industry. By standardising work scopes to reduce costly variability, some MRO organisations have quickened the transition from crisis maintenance to just-in-time maintenance and thus improving their TAT performance. By developing more effective relations with both the OEMs and the airline operators, MRO organisations have been able to electronically access inventory levels of their suppliers to enabling the transition into both just-in-time maintenance and planned maintenance. These relations also provide better access into both design data and fleet performance data that aid the transition into predictive

maintenance benefiting all stakeholders. The benefits to the adoption of Lean within the MRO environments appear to be vast especially within the context of increased globalisation.

[LITERATURE IS STRONG ON PROCESS VARIATION AND LITERATURE POORLY ADDRESSES WORK-SCOPE VARIATION – SUMMARISE AND EMPHASISE THIS POINT]

### 2.7 Assessing of the status of Lean in MRO

With the understanding of the description of the MRO industry and Lean presented in earlier section of this chapter, this section proceeds in establishing the theoretical framework for the state-of-the-art of Lean in MRO context. The approach taken in realising this outcome took on the form of not only looking at what has happened in the MRO industry but taking a holistic view of Lean engagements by the MRO industry. This involved exploring the perception of Lean by the MRO industry and why it was favoured by the industry as a way of mitigating its challenges. It then goes on to explore how Lean has been appropriated (focus) and the extent of its influence in MRO context. The strategy for Lean implementation is also explored and the factors that facilitated and inhibited its success are also presented. The strengths and weakness of literature in establishing the state-of –the-art of Lean in MRO is then examined. Figure 2.2 below describes the framework in which this outcome is achieved. It is the belief of the researcher that answers to these questions will provide a theoretical framework of MRO Lean engagements and expose the gaps in successfully realising Lean in MRO environments and indeed, the product-centric service environments.



**Figure 2.2: Development of literature review questions relating the state-of-the-art of Lean in aviation MRO**

## 2.8 Current literature of Lean in Aviation MRO context

The approach to the search strategy started by first identifying the relevant data sources, the timeframe to be considered and the keywords. Initially, a broad selection of databases was identified covering journals, conference proceedings, theses, books, and articles from trade journals examples of which include EBSCOhost, Scopus (Elsevier), ABI/Inform (ProQuest), Compendex, Inspec, and Emerald. Through these databases, a host of relevant sources of information were discovered such as the *‘European Journal for Operational Research’*, *‘Journal of Engineering Design’*, *‘International Journal of Automotive Technology’*, *‘Journal of Education for Business’*, *‘International Journal of Productivity and Performance’*,

*'International Journal of Operation and Management', 'Journal of Engineering Manufacture', 'Journal of Quality in Maintenance Engineering', 'Journal of International Economics'.*

Identifying relevant literature then required the use of an array of keywords which were carefully combined to obtain a host of articles and publications. Keywords like *'Lean', 'Maintenance Repair', 'Maintenance and Overhaul', 'Case Study', 'Toyota', 'Aviation', 'Supply Chain', 'Outsourcing', 'Aerospace'* and *'Airline'* were used and combined to identify a number of search strings as shown in Table 2.2. Some wildcards were also employed to increase the number of articles found such as *'Aero\*', 'Manufactory\*' and 'Maintenance Repair Op\*'*. The intention of these wildcards was to capture articles with spelling variances published in either 'UK' or 'American' style English and to capture articles with similar inference and conclusions but with different titles. For completeness, an Internet search was also conducted using similar techniques and processes as alluded to the library databases. Duplicate records identified by the various search strings were then eliminated. Abstracts of the remaining records were then reviewed in selecting the articles that would be relevant to the scope of this research.

<b>Search String</b>	<b>Keywords</b>	<b>Total Publications*</b>
<b>S1</b>	Lean + Maintenance	166
<b>S2</b>	Lean + Maintenance + Repair	127
<b>S3</b>	Lean + Maintenance + Overhaul	97
<b>S4</b>	Lean + Maintenance + Repair + Overhaul	36
<b>S5</b>	Lean + MRO	91
<b>S6</b>	Lean + Maintenance + Repair + Operation	39
<b>S7</b>	Lean + Maint*	194
<b>S8</b>	Lean + Aero*	174
<b>S9</b>	Lean + Aviation	126
<b>S10</b>	Lean + Repair + Operation	43

**Table 2.2: Literature keyword search results**

From the publications identified through the searches detailed, the following key publications as outline in Table 2.3 served to guide the development of the Lean engagements of the MRO industry.

	<b>Publication Title and Author</b>
<b>Interpretation</b>	<p>“Self-Maintenance works for repair firm” (Andrew <i>et al.</i>, 2008)</p> <p>“Lean Aerospace Initiative” (Massachusetts Institute of Technology (MIT), 2005)</p> <p>“Lean Maintenance” (Smith and Hawkins, 2004)</p>
<b>Motivation</b>	<p>“Aftermarket: The Ascendancy of Lean in MRO” (Mcauliffe, 2007),</p> <p>“Implementing Lean in aerospace – Challenging the assumptions and understanding the challenges” (Crute <i>et al.</i>, 2003)</p> <p>“Lean manufacturing: context, practice bundles, and performance” (Shah and Ward, 2003)</p> <p>“Is Lean manufacturing universally relevant? An investigative methodology” (James-Moore <i>et al.</i>, 1997)</p>
<b>Focus</b>	<p>“Lean Maintenance Repair and Overhaul” (Srinivasan <i>et al.</i>, 2014)</p> <p>“Lean Maintenance framework and its application in clutch maintenance” (Yile, 2008)</p> <p>“Self-Maintenance works for repair firm” (Andrew <i>et al.</i>, 2008)</p> <p>“Leaner MRO” (Mecham, 2006)</p> <p>“Lean Maintenance” (Smith and Hawkins, 2004)</p>
<b>Extent</b>	<p>“Measuring Value Creation; A case study in the MRO Business” (Wouter <i>et al.</i>, 2009),</p> <p>“War on waste: Maintenance” (Warwick, 2007)</p> <p>“A lean architecture for transforming the aerospace maintenance, repair and overhaul (MRO) enterprise” (Mathaisel, 2005).</p> <p>“Lean Engineering in the aerospace industry” (Haque, 2003)</p> <p>“Implementing Lean in aerospace – Challenging the assumptions and understanding the challenges” (Crute <i>et al.</i>, 2003)</p>

<b>Strategy</b>	<p>“Lean for the Long Term: Sustainment is a Myth, Transformation is Reality" (William and Rolfes, 2015)</p> <p>“Lean thinking in aircraft repair and maintenance takes wing at FedEx Express” (Bartholomew, 2009)</p> <p>“Defining lean production: some conceptual and practical issues” (Pettersen 2009)</p> <p>“A lean architecture for transforming the aerospace maintenance, repair and overhaul (MRO) enterprise” (Mathaisel, 2005).</p> <p>“The missing link of lean success” (Roper, 2005)</p>
<b>Critical success Factors</b>	<p>“Self-Maintenance works for repair firm” (Andrew <i>et al.</i>, 2008)</p> <p>“Making the business case for MRO” (Stall, 2005)</p> <p>“Lean Engineering in the aerospace industry” (Haque, 2003)</p>
<b>Enablers of Lean</b>	<p>“Defining lean production: some conceptual and practical issues” (Pettersen 2009)</p> <p>“Implementing Lean in aerospace – Challenging the assumptions and understanding the challenges” (Crute <i>et al.</i>, 2003)</p> <p>“The difficult part to lean Product development” (Karlsson and Ahlstrom, 1996),</p>
<b>Inhibitors of Lean</b>	<p>“Air Transport MRO Market Outlook” (Michaels, 2007)</p> <p>“Implications for Service Parts Management in the Rapidly Changing Aviation MRO Market” (Cohen, 2006)</p> <p>“Aftermarket support and the supply chain: Exemplars and implications from the aerospace” (Theodore <i>et al.</i>, 2005)</p>

**Table 2.3: Key publications identified in the review of the state-of-the-art of Lean in the MRO industry**

## **PART 3 – Analysis of literature with regards to the state-of-the-art of Lean in aviation MRO**

### **2.9 Presentation of Gaps from Literature**

With the aim of understanding the state-of-the-art of Lean in MRO context, the following section of this chapter evaluates available literature to develop comprehensive understanding Lean engagements as outlined in the Section 2.7. Whilst the outcome of this literature review is not may not be exact for all cases, the outcomes presented represent the prevalent positions on the key subjects of interest identified from literature.

#### **2.9.1 Prevalent interpretation of Lean**

There is a strong argument that the application of Lean principles alone to achieve the organisation's goal i.e. to improve the economic performance of the company and the optimisation on the Return-On-Investment-Capital (ROIC) is mere wishful thinking. This argument is premised on the opinion that Lean principles alone cannot adequately bring a company's processes under statistical control nor can it define a sustaining infrastructure of its implementation (George et al., 2003). With this perception of Lean it is no surprise that many MRO firms are implementing Lean principles in combination with other business strategies in a bid to achieve the enterprise set goals. An example of such a combination is the 'Lean' and 'Agile' approach. The integration of these two strategies as described by Andrew *et al* (2008) is based on the advantage that 'Agile' processes when introduced into the organisation would help in dealing with the issues of volatility in the market which makes forecasting difficult with irregular demand patterns, characteristic of the MRO industry. Andrew *et al* (2008) further explains that many practitioners have attempted to integrate the two approaches by proposing what is referred to as the 'leagility' and 'agilean' approach. This integrated approach was developed to create a Lean yet highly responsive operational system beneficial to MRO organisations dealing with the consequences of globalisation.

'Six Sigma' has also been regarded as a successful system capable of achieving significant gains in business performance. Apart from the strength that it has in the focus on quality and the ability to more adequately bring an enterprise process under statistical analysis, many regard Six Sigma as a business strategy while others refer to it as a well-structured and highly effective methodology that achieves improvements in product and process variation which in

turn enhances operational performance (Bossert, 2003). Companies such as Motorola and General Electric have implemented this approach (Lean principles and Six Sigma) to great success and have based their Business-Process-Improvement (BPI) around the Six Sigma concept and to good effect. Smith and Hawkins (2004) explains that *Lean* brings action and intuition to quickly pick the low hanging fruit with kaizen events while *Six Sigma* uses statistical tools to uncover root causes and provide metrics as mile markers and concludes that a combination of both provides the tools to create ongoing business improvement.

The emergence and popularity of these hybrid Lean versions within the aviation industry has led to the conclusion that:

#### Finding 1

Lean is widely interpreted as a viable within the aviation industry albeit not sufficient by itself to realise all the goals set by the organisation.

#### 2.9.2 Motivation for the adoptions of Lean

Although there were and still are challenges in the interpretation of Lean within the aviation industry, Womack and Jones (1996) was able to establish that Lean is viable and suitable in this industry. Whilst the drivers and motivators for the adoption of Lean within the aviation industry have changed over the years, the main factor(s) that consistently enables its suitability and successful implementation within the aviation MRO industry is concealed in increased business pressures and globalisation.

The need for improving operational performance in the MRO industry is intensifying (Mcauliffe, 2007). The increase in globalisation has clearly necessitated a rethink for some firms in terms of how they can organise and reconfigure themselves (Crute *et al.*, 2003). These business pressures infer that MRO organisations not only have to continually evaluate and cut TAT to be able to compete within the global market but also to cut internal cost i.e. doing more with less and subsequently, improve customer asset availability. MRO organisations are therefore searching for solutions to dramatically improve performance and enhance their competitive advantage.

The true motivation and enablers of Lean within the aviation MRO industry are measured against the perceived benefits they offer. These benefits are usually associated with the time, productivity, efficiency, space, quality, people and cost savings. However, Shah and Ward (2003) suggest that most of the empirical studies focusing on the impact of Lean on operational performance are constrained to one or two facets of Lean i.e. JIT or TQM. Notwithstanding, a Lean Aerospace Initiative study by MIT (2005), found that the introduction of Lean led to approximately 10-71 percent improvement in labour hours; 11-50 percent improvement in cost; 27-100 percent improvement in productivity; 25-81 percent improvement in factory floor space and 16-50 percent improvement in customer lead time. Other benefits included 31-98 percent improvement in inventory or work in progress (WIP) and a scrap/rework/defects/inspection improvement of about 20-80 percent. All of these benefits are indicative of the motivations for the adoption of Lean in the Aviation MRO industry.

As a result of these factors a number of major players within aerospace are pursuing Lean practices [James-Moore et al., 1997; Crute et al., 2003]. It is no surprise that more and more MRO firms are turning to the same philosophy that ensured the survival and growth of the Japanese automotive industry when faced with similar challenges.

## Finding 2

A major driver for the adoption of Lean in aviation MRO is based on the recorded outcomes of what Lean can deliver in contexts similar to MRO business and performance pressures.

### 2.9.3 Prevalent focus of Lean implementation

Mecham (2006) stresses that although the principles of Lean implemented to great success in the manufacturing world are similar to those of the maintenance industry; there still remains scepticism about its focus. The cynicism conversely lies in the thought that the earlier exists in a manufacturing environment and the later exists predominantly within a service environment (albeit product-centric) and therefore it is not easy to directly transfer either's perception in their approach to Lean.

Furthermore, the introduction of Lean into the aviation MRO industry has led to the coining of the term 'Lean Maintenance' to capture the application of Lean to the industry (Smith and

Hawkins, 2004). Yile (2008) delineated the different phases and their corresponding focus in their interpretation of Lean maintenance. The different expressions range from a focus on increasing up-time and reliability to reducing operational cuts to the bare minimum. Other expressions of the focus of Lean incorporated overlapping Lean tools in order to reduce waste. Although there is the indication that MRO organisations are now beginning to see value creation potential in Lean application, this however, is not prevalent within the industry (Yile, 2008). Whatever the expression, the underlying focus for the application of Lean currently is essentially, the reduction of waste (Smith and Hawkins, 2004). The increased focus on waste elimination however suggests that the focus of Lean implementation is to reduce process variation as opposed to mitigating the challenges that come with work-scope variation (Srinivasan *et al.*, 2014).

Andrew *et al* (2003) suggested that with OEMs employing Lean tools and techniques to build more reliable equipment requiring less servicing and increased time-between-overhaul (TBO), the need for customisable MRO work and cost pressures by airlines to have lower service costs and less aircraft downtime is significantly increased. They suggested that more OEMs are opting for the use of Lean tools and techniques in the pursuit of ‘*value creation*’ as compared with the MRO industry where Lean is presented as a tool for achieving the main aim of ‘*reduction*’ of waste. With Baines *et al* (2007) highlighting the danger of crossing and misinterpreting ideas put forward by Lean especially when the paradigm between the principles, tools and techniques associated with Lean have not been properly established, this has led to the conclusion that:

### Finding 3

The focus of Lean within the aviation MRO industry is predominantly directed towards *waste reduction* (process variation) as opposed to the creation or the enhancement of *value*.

#### 2.9.4 Extent of Lean adoption

Haque (2003) argued that although the aerospace industry was initially reluctant to the adoption of Lean, it is fully viable within the aerospace industry. Although Lean is gaining popularity within the aerospace industry and can be implemented in small and large companies alike, there is still a lack of sustainable methodology as well as proper application

of supporting management tools and technology. This may be attributed to the fact that Lean is increasingly being seen by the aerospace industry (particularly MROs) as a viable tool to improve the overall performance of the company (Mathaisel, 2005). The paucity of literature on the subject of Lean within the MRO industry serves as evidence of the industry's initial reluctance to its adoption compared with other industrial sectors.

Although the MRO business is vulnerable to both global and local market fluctuations, the specialised nature of the industry requires that its general internal structure is defined and conventional which is favourable for the adoption of Lean. The challenge however is that although significant strides have been achieved in the adoption of Lean, the extent of its adoption and the maturity across the whole MRO industry cannot be ascertained. Literature suggests that quite a lot of companies have embarked on their Lean journeys since the late 1990's, however, the spread of its application is significantly smaller in comparison to other industrial sectors especially the automotive industry (Crute et al., 2003; Warwick, 2007; Wouter et al., 2009). This has led to the conclusion that:

#### Finding 4

There is strong emphasis on the adoption of Lean within the MRO industry, although the extent of its adoption is difficult to ascertain.

#### 2.9.5 Prevalent strategy for Lean implementation

Pettersen (2009) after successfully confirming the validity of the Lean paradigm, stressed that the overall goal of an organisation will be responsible for the way in which the concept is approached. Although he identified that there are generally two different types of goals: *internally* focused goals (Feld, 2001; Liker, 2004) and *externally* focused goals (Womack et al., 2003; Bicheno, 2004) he also stressed that the formulation of goals is essential to the Lean implementation approach. The lack of a precise definition and goal formulation will lead to difficulties in determining whether changes made in an organisation are consistent with Lean principles or not and this will subsequently lead to difficulties in measuring its effect and effectiveness (Parker, 2003).

Literature review reveals that different approaches have been adopted in Lean implementation programmes within the aviation MRO industry which complements the findings by Pettersen (2009). For example, Lufthansa Technik in its implementation journey has adopted a strategy similar to the *Kaizen Blitz* approach (Tapping et al., 2002) which has recorded great success in its formative years. They have internally interpreted the Lean concept and developed a three phase approach to its implementation: ‘*Technical Systems*’ (Lean tools and techniques), ‘*Management Infrastructure*’ (monitoring and continuous improvement measures) and ‘*Attitudes and Abilities*’ - aligning the working culture and mentality with Lean philosophy i.e. paradigm shift<sup>9</sup>.

Mathaisel (2005) postulated a ‘transformational’ approach to the adoption of Lean within the aerospace MRO industry. After careful consideration of different approaches including the *design-build* approach proposed by Pearce and Bennet (2005), and the *Kaizen Blitz* approach proposed by Laraia et al., (1999), Mathaisel (2005) proposed the *Lean Enterprise Architecture* (LEA) implementation programme. He described it as a “*structured sequence of activities for the transformation of the MRO enterprise from a current state to a desired future Lean condition by using phased system based on transformation life cycle*”.

Conversely, FedEx have adopted a different implementation strategy by completely redesigning its Los Angeles Airport facility in order to deal with the challenge of reducing cost and the need to boost revenue. The focus at the facility was to use Lean principles to increase its capacity using the same equipment and staff (Bartholomew, 2009).

In many contexts, Lean success is often times regarded as the existence of a “Kaizen culture”. However, this point was discredited by William and Rolfes, (2015); Roper (2005), Bamber and Dale (2000) on the assumption that there is no roadmap for achieving this kaizen culture and without proper control; most organisations will run out of time and patience before they discover this path to leanness. Mathaisel (2005) also explained that benchmarking oneself against best internal operations or against external direct competitors or against best external functional operations or against other generic functions regardless of the industry can be one measure of the value of one’s relative leanness.

---

<sup>9</sup> Hawker Pacific Aerospace “Hawker Pacific Aerospace: Part of Lufthansa Technik Landing Gear Division”. <http://www.hawker.com/> (Accessed September, 2009).

Although these organisations have recorded significant progress and profits that can be linked to their Lean implementation programmes employing several strategies, with everyone left to their own devices on their Lean journey the effectiveness and correctness of many Lean programmes will become questionable. This is because the numerous implementation strategies suggest that the overriding objective(s) that ensure the successful implementation of Lean within MRO organisations is yet to be defined. This has led the authors to conclude that:

#### Finding 5

Various implementation strategies have been employed in the adoption of Lean and these strategies, while producing significant benefits in the short term, the sustenance of these benefits in the long term remain unclear.

#### 2.9.6 Critical success factor for Lean implementation

The ‘pressures’ forcing the MRO industry to turn to ‘Lean’ as a saviour are tangible (Stall, 2005). Andrew *et al.* (2008) suggests that in order to successfully compete on a global scale, there should be a clear and novel way by which MRO process strategy tackles the real issue of improving operational facility performance and reduce variation in key-performance-indicator attainment that achieves long-term economic sustainability. As already established by Karlsson and Ahlstrom (1996), a company does not achieve Lean product development simply by implementing Lean techniques alone, instead, a successful move towards Lean requires approaching these interrelated techniques in a coherent way. Successful Lean implementation will require the involvement of everyone up and down the ranks in the company as seen from both literature and case studies (Baines *et al.*, 2006).

William and Rolfes (2015) suggest that successful realisation of Lean requires first a common language of business to be able to communicate. The common language proposed by William and Rolfes (2015) stems from a Lean Management System model that encompasses Leadership, Process and Growth as the model to drive business performance. The core of this management model has five elements which include: Clarity of Purpose, Standard Work, Transparency, Accountability and Innovation. All of these responsibilities

will require strong leadership skills. Literature (Haque et al., 2004) suggests that these responsibilities are driven by targets and deadlines. Therefore, the person(s) tasked with these responsibilities should have proven engineering excellence, leadership skills to control the programme and must be able to effectively interpret customer satisfaction into practical engineering practices and vice-versa within the scope permitted by the Lean paradigm (Haque, 2003; Liker, 2004).

#### Finding 6

A critical success factor for Lean realisation extends beyond the deployment of Lean tool and techniques but more importantly, the management (leadership) and the management system that actively encompasses every function and everyone in the organisation.

#### 2.9.7 Prevalent Inhibitors for Lean advancement in MRO

There is no doubt that the whole of the aerospace industry is now warming to the benefits and opportunity that are proposed by Lean to eliminate 'waste' within its operations and the Lean revolution is underway within the industry (Crute et al., 2003). However, there are some contextual factors that have inhibited the application and advancement of the Lean paradigm within the aviation industry. With very little published information on the challenges of Lean within the MRO industry, the following key inhibitors identified from literature review reflect the inhibitors of Lean within the aviation industry as a whole.

#### *Lack of comprehensive understanding of Lean*

Crute *et al.*, (2003) suggested that the lack of comprehensive understanding in the interpretation of Lean served as an inhibitor to the early adoption of the Lean paradigm within the aviation industry. They suggested that one of the earlier misconceptions that inhibited the transfer of Lean from the automotive industry to the aviation industry was the challenge of adapting Lean from an industry of high-volume capacity (automobile) to an industry of low-volume capacity (aircraft). However, the study by MIT (2005) provided rich details as to the significant benefits of Lean in the aviation context. Srinivasan *et al.*, (2014) also validate Lean in aviation MRO through positive outcomes recorded in Delta Airline

TechOps and Warner Robins Air Logistics Centre. It is even argued by Womack *et al.*, (1996) that the aerospace industry may be at an advantage over automotive in the application of Lean principles, on the basis that lower volume capacity infers a closer association to the Lean ideal of single piece flow.

Another major misconception of Lean that inhibited the application and advancement of the paradigm is the confusion that arose from the different Lean capabilities across countries, from firm to firm but more so within firms. The differing interpretation of Lean led Crute *et al.* (2003) into a case study research with the conclusion that Lean capabilities are ‘*plant*’ specific. The uncertainty surrounding the interpretation and understanding of Lean contributed both to the reluctance to its adoption and/or the success of many Lean implementation programmes within the aviation industry. Pettersen (2009) also came to the similar conclusion that the capabilities of Lean have to be fully understood and appreciated before any successful implementation can be achieved.

Lean production requires a change in attitudes and behaviour not only of managers but also of employees (Bamber and Dale, 2000). While the aerospace sector may have some advantages in implementing Lean, the challenges of implementation are real and prove difficult for many firms. Karlsson and Ahlstrom (1996) suggest that traditional ways of thinking and practices are difficult to shed and radical change would be difficult and require an immense amount of effort to overcome. The introduction of Lean into an organisation will in most cases translate into the change of the existing working *culture* to one where the employees themselves look for potential problems, seek out and eliminate waste, and take responsibility for continuous improvement, quality assurance and maintenance. Bamber and Dale (2000) suggest that the lack of a concise understanding of Lean by all employees will somewhat inhibit the advancement of Lean in organisations where it has been adopted or increase the reluctance of other organisations to adopt the philosophy. Consequently, it is important for researchers and practitioners to develop a comprehensive understanding of the Lean paradigm in order to demystify the myths surrounding Lean that have inhibited its adoption and successful implementation (Theodore *et al.*, 2005).

## Finding 7

The lack of comprehensive understanding on Lean and its capabilities is evident within the aerospace industry thus hindering the successful *adaptation* of Lean to be plant specific.

### *Appropriating Lean incorrectly to address challenges characteristic of the MRO industry.*

It is also not uncommon for some of the technology in avionics and weapons systems to be outdated much earlier than expected either because suppliers cease production of some of these parts due to cutbacks in procurement (e.g. military) or in order to pursue higher-demand and more profitable commercial opportunities (Meadows, 1997). Similar logic also applies to the issue of *difficult-to-find* parts (Theodore et al., 2005). Due to the difficulty in accurately predicting these scenarios, decisions have to be made by MRO organisations to hold some of these components in excess inventory earlier on in the product's life cycle (Silverman, 2000). With excess inventories held by many MRO firms, there seems to be a contradiction with the ideals of Lean as discussed by Ohno (1988).

Also, with high labour rates forcing the majority of aviation MRO type logistics carried out in Europe and North America to move to lower wage countries particularly to Asia, Eastern Europe and Central America as a way of reducing cost, the associated supply chain process supporting the MRO industry becomes more complicated (Michaels, 2007). To minimise the issues that come with complex supply chains, the majority of MRO organisations tend to hold excess levels of inventory.

In other instances where excess inventory is not kept, the inherent variability of repair work unlike repetitive manufacturing is difficult to forecast until a full inspection is accomplished. However, upon inspection of an unserviceable aircraft, the “unpredicted” or “emergent” rework or damaged parts found will then have to be ordered on an expedited basis (Cohen, 2006). The danger inherent is that these uncertainties result in delays which could disrupt the original schedule and final delivery of the overhauled items. In order to overcome these challenges, it is not unusual for MRO organisations to hold more than the required inventory which again contradicts the ideals of Lean as explained by Ohno (1988). Whilst all of these challenges are characteristic of the MRO industry, the limited perception of Lean (to only address waste as witness in manufacturing context) subsequently informs the focus of its appropriation (Srinivasan, *et al.*, 2014). Appropriating Lean to address process variation

issues and expecting an outcome that mitigates work-scope variation will eventually lead to frustration and ultimately hinder the advancement of Lean. Thus, the clarity of purpose required by the management (leadership) and evident in the management system should portray an acute understanding of the context of adopting which will inform the mode of Lean engagement. This has led to the conclusion that:

#### Finding 8

Incorrectly appropriating Lean due to a lack of understanding of the characteristics of the MRO industry will result in outcomes that may hinder the advancement of Lean in the MRO industry.

#### 2.9.8 Strengths and Weakness of Existing Literature

It was observed from literature that there was strong emphasis on the application of LEan to address *process variation* and less emphasis on the application of Lean to *work-scope variation*. Both aspects are characteristic of aviation MRO operations however a defining feature of MRO is *work-scope variation*. Also, although the number of direct literature pertinent to Lean in the aviation MRO context was relatively fewer in comparison to the manufacturing context, it did provide a basis that was used in assessing the state-of-the-art of Lean in MRO context. The lack of direct literature may be indicative of the relatively newer introduction and emphasis of Lean into the MRO context. However, with the understanding that Lean is plant specific (Crute *et al.* 2003) and conversely, the various strategies in Lean engagement by MRO organisations, there was a wide spectrum of case exemplars that portray how Lean has been applied within aviation MRO context. These include authors such as:

- Srinivasan et al., (2014): “Lean Maintenance Repair and Overhaul: changing the way you do business”
- Andrew et al., 2008: “Self-Maintenance works for repair firm”
- Wouter *et al.*, (2009): “Measuring Value Creation; A case study in the MRO Business”
- Mathaisel, (2005): “A lean architecture for transforming the aerospace maintenance, repair and overhaul (MRO) enterprise”
- Theodore et al., (2005): “Aftermarket support and the supply chain: Exemplars and implications from the aerospace”

The case exemplars presented by such authors provided an insight not only as to what Lean was able to achieve but also the awareness of the characteristic inherent of the MRO industry. Whilst the outcome of these Lean engagements was usually successful, it was observed that most of the lean engagements were directed as process variation and not at addressing the challenges that arise from work-scope variation.

Furthermore, it was observed that a critical success factor for the advancement of Lean in MRO context was the leadership and the management system (William and Rolfes, 2015); however, it was not clear what role the leadership played in these successes and also what management system was deployed in the realisation of this outcomes. Conversely, although the aerospace industry as a whole has woken up to the possible benefits that could be reaped from Lean, many practitioners and company managers are still sceptical about the results and are thus, still piloting different adaptations of Lean. This scepticism and underlying lack of precise understanding and clarity on the subject may also lead to the paucity of literature on the subject pertaining to the MRO sector.

#### Finding 9

More practical engagement with the MRO industry is still required to fill the gaps in knowledge resulting from the paucity in literature regarding the Lean in MRO context.

### 2.10 Discussion

It is clear from literature that in order to mitigate the continuously increasing competition within the aviation MRO industry, many organisations are turning to Lean philosophy especially because of the benefits it is perceived to offer. This is premised on its success within the automotive industry. However these perceived benefits have to be clearly understood in the context of the environment where it is to be implemented.

Firstly, it has been established in literature that there is an increasing demand for reduced TAT from airline operators. This demand is sometimes even considered as one of the order-winning criteria especially when dealing with LCC who cannot afford the lengthy downtime

associated with aircraft maintenance. However, attention also has to be drawn to the fact that, in most cases, only very limited information is known about the condition of the product before it is sent for overhaul. This therefore presents a puzzling situation where the customer has been guaranteed a delivery date for the overhauled product based on speculation about the condition of the product and consequentially, the required MRO operations and the associated time is not known. Although the ideals of Lean suggest its suitability within such an environment in that it is supposed to remove wasteful operations in the overhaul process, the huge uncertainties involved also point to the challenges that it must overcome for it to be considered as successful within this industry.

The inclusion of OEM in the MRO market through asset management programmes (servitization) introduces a new dimension to the competition. OEMs are able to install remote monitoring programmes to the product that provide up-to-date information on the condition of the product which enhances their competitive advantage. This also means that they know the maintenance operations that are required before actual receipt of the product. This informs their planning and supply functions, making it a more conventional environment for the implementation of Lean. However, this is a relatively new but growing phenomenon within the aviation industry and particular to certain sectors (engine). These genres of remote monitoring programmes are capital intensive and a luxury that most traditional MRO organisations cannot afford simply because of the huge investments and because the proprietary rights of the product still remain with the OEM or the airline operator. Therefore, this major and peculiar challenge of the industry presents a prospective area for further research especially with its interaction with Lean.

Furthermore, the context of its implementation also suggests that a thorough understanding of the Lean philosophy has to be achieved in order to ensure its relevance, effectiveness and sustainability within the industry. As identified in literature, there cannot be a direct transference of Lean principles from one industry (automotive) to another (aviation). This is not indicative of an inherent limitation of the Lean philosophy, but that the emphasis of its application in practice may differ between industrial sectors albeit having similar goals. A significant amount of current literature suggests that more clarity on the philosophy of Lean is still needed within the industry especially considering current focus and interpretation of Lean.

There is a growing proposition that Lean focuses on the creation of value as opposed to the elimination of waste. Although both motivations are closely linked, they could be misleading in practice. The creation of value infers a greater threshold for inefficiency in the production system as far as value is created whilst the focus of waste elimination holds a much lower tolerance for inefficiencies in the production system. This is also indicative of the clarity that is required on the adoption of Lean by the industry.

As pointed out in literature, all of these challenges present an exciting opportunity for Lean in this industry with some companies already reporting successes directly linked to Lean implementation. Although the extent of its application within the industry cannot currently be ascertained; the robustness of the Lean philosophy will be judged by its performance in this industry.

### 2.11 Chapter Summary

This literature review as summarized in Table 2.4 indicates that Lean is viable within the MRO sector of the aviation/aerospace industry. However, the various Implementation strategies and a distinct lack in the understanding of the factors that contribute to the long-term success of its application, suggest that several Lean implementation programmes will become questionable over time. This will subsequently lead to questioning the effectiveness of Lean in mitigating industry challenges and whilst this research is not focused on re-inventing Lean for the MRO context, its main focus is centred on how Lean can be successfully realised within this context in such a way that it enhances competitive advantage.

It was also observed from literature that there was a belief that Lean alone is insufficient to achieve a company's goals and thus has to be combined with other tools such as Six Sigma etc. This belief might either be as a result of the lack of understanding of the subject or an inherent fallibility of the paradigm itself. Whatever the case, the capabilities of Lean still require clarity especially in its adaptation to the MRO industry.

The unique characteristics of the MRO industry as established in earlier section of this chapter requires that the interpretation of Lean is specific to the MRO industry and as such,

should be adapted in a way that minimises the consequences of all these inherent MRO challenges. Although the prevalent view as observed from literature centred on waste reduction, a limited view of Lean in this sense could affect the effectiveness of its realisation, particularly in the long term. This is because waste reduction takes mainly into consideration process variation issues and not necessarily work-scope variation which is inherent of the MRO operations. Thus, this research presents an approach that facilitates holistic Lean engagement to ensure successful realisation within MRO context. This holistic Lean engagement extends beyond looking at Lean purely from a ‘shopfloor’ perspective, but also takes into consideration how Lean can be applied to enhance competitive advantage.

Literature within this field (i.e. Lean within the MRO industry) remains scarce compared to other industries where these principles have already been established over time. However, the surge of companies welcoming the Lean idea suggests that this will encourage more academic research providing better and accurate documentation of proven practices and methods for the successful implementation and the growth of Lean within this sector. The newness of this paradigm to the MRO industry means that many practitioners are still ‘experimenting’ with these principles and there is scope for further research into the ideal lean framework for the aviation MRO industry. This involves mapping out the most suitable implementation approach and customised measuring metrics to benchmark the success of its implementation. This will also involve developing a qualitative and quantitative system and/or methodology that sustains the successful implementation of Lean. There clearly is scope for future research in this area.

	Topic	Key Gaps
1	<b>Interpretation of Lean</b>	Lean is widely interpreted as a viable tool within the aviation industry albeit not sufficient by itself to realise all the goals set by the organisation.
2	<b>Motivation of Lean</b>	A major driver for the adoption of Lean in aviation MRO is based on the recorded outcomes of what Lean can deliver in contexts similar to MRO business and performance pressures.
3	<b>The Focus of Lean</b>	The focus of Lean within the aviation MRO industry is predominantly directed towards <i>waste reduction</i> (process variation) as opposed to the creation or the enhancement of <i>value</i> .
4	<b>Extent of the adoption of Lean</b>	There is strong emphasis on the adoption of Lean within the MRO industry, although the extent of its adoption is yet to be ascertained.
5	<b>Lean Implementation strategy</b>	Various implementation strategies have been employed in the adoption of Lean and these strategies, while producing significant benefits in the short term, the sustenance of these benefits in the long term remain unclear.
6	<b>Critical factor for successful Lean Implementation</b>	A critical success factor for Lean realisation extends beyond the deployment of Lean tool and techniques but more importantly, the management (leadership) and the management system that actively encompasses every function and everyone in the organisation.
7	<b>Inhibitors of Lean</b>	<p>The lack of comprehensive understanding on Lean and its capabilities is evident within the aerospace industry thus hindering the successful <i>adaptation</i> of Lean to be plant specific.</p> <p>Incorrectly appropriating Lean due to a lack of understanding of the characteristics of the MRO industry may result in outcomes that will hinder the advancement of Lean in the MRO industry.</p>
8	<b>Strengths and weakness of Existing Literature</b>	More practical engagement with the MRO industry is still required to fill the gaps in knowledge resulting from the paucity in literature regarding the Lean in MRO context.

**Table 2.4: Summary of key Findings**

### 3. RESEARCH PROGRAMME, AIM AND OBJECTIVES

The literature review documented in chapter 2 identified a few findings several of which this study seeks to address. This chapter details the research problem and the particular area of interest which this research seeks to further investigate presented in section 3.1. The research aim and objectives are presented in section 3.2 and the research programme which describes how each of these objectives are achieved is presented in section 3.3. A summary is then presented at the end of the chapter in section 3.4.

#### 3.1 Research Problem

Over the years, the nature of the challenges faced by the MRO industry has changed dramatically. The initial challenge for the MRO industry was purely ‘production goals’. These goals were driven primarily by the concentration on core competences. Almeida (2005) demonstrated how airline-operated MRO organisations tended to be ‘most competitive’ within the early years of product manufacture because of their substantial inventory and geographic presence, which gave them the ability to serve customers around the clock. However, in the later stages of the life cycle of parts the economies of scale, obtaining licenses from OEMs to maintain and repair specific systems and specialising in state-of-the-art inventory control measures to reduce costs, favours independent MRO organisations. Although the life cycle of the product(s) to a large extent dictated who was most likely to carry out the maintenance operation(s), based on their core competence, the main challenge however, was purely focused on production goals.

The overall challenge for the MRO industry is now very different. The ever changing market forces now require that apart from the initial ‘*production*’ goals, MRO organisations need to increase the margin between stock and value by considering every possible resource to maximise operational efficiency and minimise effort i.e. optimise and streamline business operation (Stall, 2005). This means that the aviation MRO industry has to manage effectively how it minimises overall maintenance costs, reduces aircraft turn-around times (TAT) and establishes return on experience in the form of accurate job standards. MRO organisations also find that they have to contend with wildly varying asset types and configurations more than ever before. Maximising the facility capacity and ensuring compliance with the

customer's maintenance programme is another major issue within the MRO aviation industry (Mathaisel, 2005).

There are consequently many initiatives to improve enterprise-wide productivity as increasing productivity has a universal appeal to any manufacturer faced with increasingly intense global competition (Lewis, 2000). Detailed study into the Lean paradigm led Womack *et al.* (1990) to argue the position that Lean principles are applicable to any industry, a proposition that was supported by Haque (2003) as directed towards the aerospace industry as a whole.

The argument for the adoption of Lean is usually made considering the remarkable commercial performance of Toyota. It is important to point out that the success and discovery of Lean principles within the Japanese automotive industry was during a severe economic climate (Mathaisel, 2005) similar to the current 2008/2009 global economic meltdown. At the end of 2003, Toyota published profits of 8.3 billion US dollar; greater than the combined profits of General Motors, Chrysler and Ford establishing Toyota as one of the top three car sellers in the USA (Liker, 2004). According to company figures, Toyota in 2007, sold 2.348 million units in the US (the world's largest car market) with General Motors selling a total of 2.26 million. It is therefore no surprise that the success of Lean within the automotive industry has led to its ubiquitous proliferation into other industries.

The express approval and success record of Lean in the automotive industry has signalled other industrial sectors to awaken to the immense benefits that this philosophy has to offer (Melton, 2005). Within the aviation industry for example, some MRO firms have been able to cut TAT dramatically by employing tools that relate to Lean principles. The most important factors in an airline's selection of an MRO supplier are typically quality, TAT and price, in that order. However, special circumstances can shift customer priorities which could mean that the priority changes. For example, an airline could have a situation where there are temporarily more aircrafts than needed to deliver its schedule thus giving TAT lower priority. But for a fleet size right for its network, a short TAT is key to minimising total maintenance costs. The progress in reducing TAT should prove to be a strong competitive advantage (Canaday, 2009). MRO organisations have to increasingly deal with wildly varying customer priorities and there are strong indications that suggest the introduction of Lean into the industry offers significant benefits in mitigating this conundrum.

However, whilst the Lean tools techniques which as observed from literature are viable in the aviation MRO can be applied to great benefit, simply deploying these tools does not necessarily translate into business growth, financial success or even competitive advantage (Srinivasan *et al.*, 2014). Indeed, Srinivasan *et al.*, 2014 presents a case of an MRO facility that faced imminent closure as a result of poor financial performance. The response to the crises was a series of Lean event and the deployment of Lean tool and techniques. Although the results were impressive in terms of significant reduction in inventory, improvement in the efficiency of the workers, better machine utilisation etc, there was only a marginal improvement in the financial performance of the company. Although there were some noticeable reductions in the capital cost (inventory reductions) and operating cost (reduced overtime), revenues had not increased and as such, not much had changed in the financial position of the company. Whilst all the Lean efforts of the company was required in addressing the process issues, the constraint on profitability was the market, and therefore, the focus should have included growing the market. Since shorter TAT remain a strong proposition for customers, perhaps inclusive with all the other Lean efforts should have been an increased focus on reducing the time to complete the maintenance inputs as a growth strategy and market differentiator. As such, growing the business would have meant that any additional revenue from the new business less the material cost would have made a significant positive impact to the financial situation of the company.

Furthermore, and also as identified from literature that incorrectly appropriation of Lean due to a lack of understanding of the inherent characteristics of the MRO industry could result in unintended outcomes, it is vitally important to avoid a blind transference of Lean from the manufacturing context (where Lean originates) into the aviation MRO context. Although a number of the tools and techniques are used in both context, Lean cannot be viewed as a set of rules and techniques that can be applied universally. The unique challenges faced by MRO organisations result in some traditional Lean tools being either not applicable or requiring adaptation to the MRO environment (Srinivasan *et al.*, 2014). For example, “mixed-model scheduling” is used in the manufacturing context to alternate the scheduling sequence among the various models produced at a facility so as to achieve small production batch sizes and a more balanced workload. However, in MRO context, may not apply because MRO operations are typically not performed in a batch-manufacturing mode due work-scope variation.

Whilst the manufacturing context is typically associated with high-volume, low-variety production, the MRO context is usually typified by low-volume, high-variety production and there are a number of characteristics that differentiate the two. Relative to high-volume manufacturing environments, in an MRO environment (Srinivasan *et al.*, 2014):

- The rate of demand and the mix of products are more variable.
- A significant portion of the MRO input may be ‘over and above’ what would have been estimated as the initial work package. This work is not part of the standard work package and is different for each item and as such, there is significant variation in the parts requirements, the work-scope and the flow path, even for similar products.
- Much of the additional work scope and part requirements are not known in advance but are only revealed during the course of the repair process.
- Some parts have long and unpredictable lead times.
- After disassembly and inspection, a significant portion of the work is handed off to remote shared-capacity back-shops or external contractors.
- Many different tasks compete for the same shared resources.
- Work-in-progress (WIP) inventory represents not just inventory in the traditional sense but a piece of the customer’s equipment that is out of service and is not generating revenue for the customer.
- The production capacity may be worker constrained as opposed to equipment constrained.

The distinct characteristics that differentiate the MRO context from the Manufacturing context thus undergird that there cannot be a direct transference of Lean from one context to another. Thus, even though they are closely related and complementary of each other, it is one thing to successfully apply Lean tools and techniques within the MRO context, it is another thing to adopt a Lean approach in enhancing competitive advantage. As such, this research will seek to establish how Lean can be successfully realised within MRO context and also how Lean can be applied to enhance competitive advantage within MRO context. The following section defines more accurately, the scope of the study contained in this research.

### 3.2 Aim and Objectives

With the understanding of Lean, the MRO industry and the findings from MRO Lean engagements (Chapter 2), the aim of this research has been scoped to:

*Understand how the value proposition of the MRO is realised and present a comprehensive approach as to how Lean can be deployed within this context to enhance competitive advantage. This research will also enable the assessment of performance gaps and aid the user in aligning strategy with the expectation of Lean to achieving competitive advantage.*

In seeking to achieve this research aim the following research objectives were set. These objectives serve as ‘mile makers’ in the journey of realising this aim. The objectives to be achieved by this research are:

1. Establish the status of MRO Lean engagements through Literature review and empirical study (especially with regard to the *interpretation, motivation, focus, extent, strategy* of implementation, *critical success factors* and *inhibitors* of Lean application).
2. Determine the means through which the MRO value proposition is realised and identify how competitive expectations are mediated through this means.
3. Establish what competitiveness within MRO context comprises of and develop the approach that employs Lean application to enhance competitive advantage.
4. Validate the proposed approach of Lean application to enhance competitive advantage using a case exemplar.

### 3.3 Development of Research Programme

This section gives an overview of the research programme presented in section 1.3. It illustrates the structure of the investigation carried out to realise the aim and objectives outlines in section 3.2. The research details and outcomes relating to each phase of the research are however contained in the following relevant chapters.

It is important to point out that this research is informed and guided by literature. To compliment the literature, primary data was also sought by engaging the industry facilitated by means of an industry survey and structured interviews. The methodology applied during industry engagements was structured and supported by literature. Baines (1994) and Lim et al., (2007) advise that there are three approaches for the development of research. These approaches are:

1. Develop the *methodology* based upon existing knowledge from within the literature
2. Critically evaluate all *methodologies* found within the literature
3. A hybrid approach which combines elements of both approach 1 and 2  
(Chandraprakaikul, 2008).

Whilst no new methodology was developed from this research, Approach 3 is largely used in the development of the study contained in this thesis. The research is based upon critical evaluation of existing knowledge and adapting it to suit the field of interest. Evaluation of the outcome of this research is carried out to test its relevance and suitability. This approach is apparent across all phases of the research programme which can be grouped into 3 basic stages as presented in Figure 3.1.

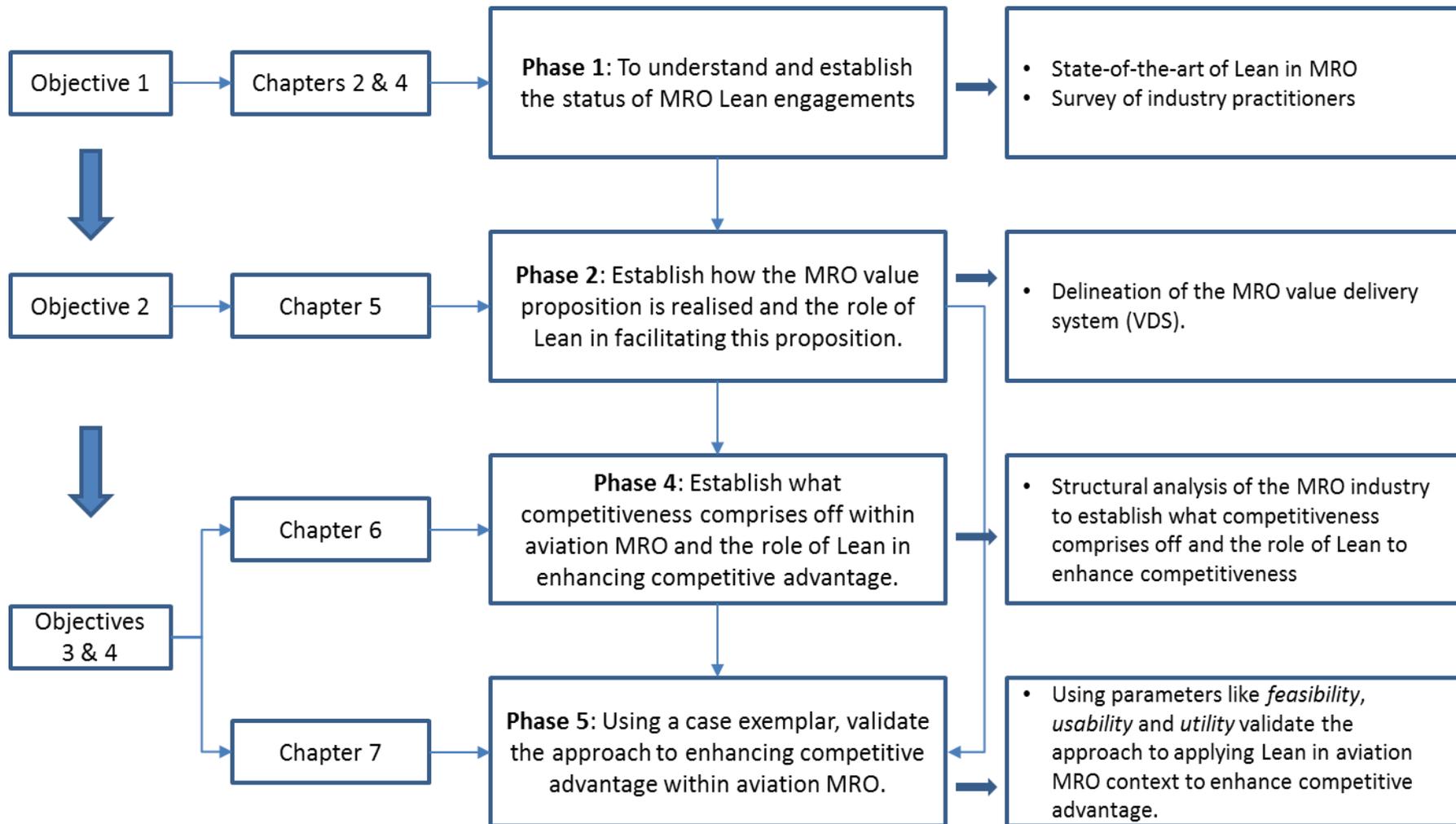


Figure 3.1: Structure of research programme

### 3.3.1 Phase 1: Understand and establish the status of MRO Lean engagements.

The proven success of Lean in the manufacturing industry (particularly the automotive industry) and its increasing proliferation into other sectors including the aviation MRO industry signalled the need for more conscientious investigation into its suitability and utility in this new environment. With the ubiquitous application of Lean in MRO context it, therefore became necessary to establish what the status of MRO Lean engagements. Establishing this status took on two forms – Literature review and an industrial practitioner engagement. Whilst the literature review provided an insight into prevalent MRO Lean engagement, the paucity of direct literature primarily about Lean in MRO necessitated obtaining a broader view of Lean in MRO context. Also, to validate the ubiquitous application of Lean in MRO, the industrial engagements also contributed to wards demystifying the suitability, prevalent approach of Lean engagements but also, provide more clarity into the make-up of the MRO industry.

**Methodology:** The methodology used in realising this phase was critical examination of literature and an empirical study facilitated by an industry-wide survey.

**Deliverable:** the outcome of the literature review is presented in chapter 2 of this thesis and the empirical study presented in chapter 4. The synthesis of both studies is what was used in establishing the status of Lean engagements in aviation MRO context. This is also presented in chapter 4. Based on this outcome, it became evident that the application of Lean albeit proven to provide significant positive results in operation does not necessarily translate into competitive advantage. This informed the following phases of this research.

### 3.3.2 Phase 2: Delineate the means through the MRO value proposition is delivered.

Based on the outcome of Phase 1 which indicated that “...prevalent approach to Lean engagement within the MRO industry was not holistic...and very operationally focused...” the next phase of the research programme focused on establishing the complete means through which the MRO value proposition is realised. If the purpose of Lean is to eliminate waste and enhance value, it is the believe of the researcher that the deployment of Lean to the complete means through which MRO realises it value proposition (and not partial elements of

it) that results in successful Lean implementation what support enhanced competitive advantage. The delineation of this means resulted in the development of the MRO value Delivery system.

**Methodology:** Critically evaluation of literature to understand how value is delivered was used in developing a basic framework. This framework was adapted to suit the MRO context (which was subsequently tested in Phase 4 using a case exemplar)

**Deliverable:** The delineation of the MRO Value Delivery System (VDS). This system encompasses not only the *operational* value dimension (where Lean efforts have been predominantly directed as evidenced from Phase 1), but also importantly, the *strategic* and *economic* value dimensions. It became readily apparent that the reason why the application of Lean albeit leading to significant positive operational outcomes did not translate into competitive advantage was because the Lean engagements have been largely limited to the operation dimension of the VDS. All of this is presented in chapter 5 of this thesis.

### 3.3.3 Phase 3: Establishing the competitive landscape of the MRO industry, the competitive routes and the role of Lean within this backdrop.

Another outcome from Phase 1 is that “...*clarity is still needed with how Lean can be applied within the aviation MRO context to facilitate competitive advantage...*” Thus, the next phase of the research addressed what competitiveness within the aviation MRO consisted of. Structural analysis of the MRO industry was conducted to fully understand the forces of competition and the competitive routes within the industry. Establishing the competitive landscape provides an additional focus to Lean application within the MRO VDS. Also, establishing the competitive routes clarifies the options for competition and how performance is measured across those options. The role of Lean in enhancing competition across each option is then developed.

**Methodology:** Again critical evaluation of literature was carried out and the Porter’s (1985) model of competition was favoured. Using the model, the competitive profile of the MRO industry was mapped to provide clarity to the competitive landscape and the competitive routes. The competitive routes serve as the overriding determinants to focus of Lean application.

**Deliverable:** The outcome of this phase resulted in the development of aviation MRO competitive landscape. The competitive routes were established and the role of Lean application along these routes was clarified.

#### 3.3.4 Phase 4: Validate the approach to Lean application within MRO to enhance competitive advantage.

The final phase of this research involved validating the approach to Lean application to enhancing competitive advantage within the aviation MRO industry proposed by this study. This was achieved using a case exemplar (Lufthansa Technik Landing Gear Services, UK) using Platts *et al.*, (1998) parameters of *feasibility*, *usability* and *utility*.

**Methodology:** The validation facilitated by the case exemplar was achieved using semi-structured interviews (protocols of which are detailed in chapter 7). Critical evaluation of literature was also carried out to provide a means of assessing the objective *utility* of the approach to Lean application. This resulted in the use of a modified Failure Mode Effect and Analyses tool to operationalise the VDS (outcome of Phase 2) and the approach to Lean advocated for.

**Deliverable:** The validation of the approach to Lean application which encompasses all value dimensions of the VDS with a stronger focus to enhanced competitive advantage.

### 3.4 Chapter Summary

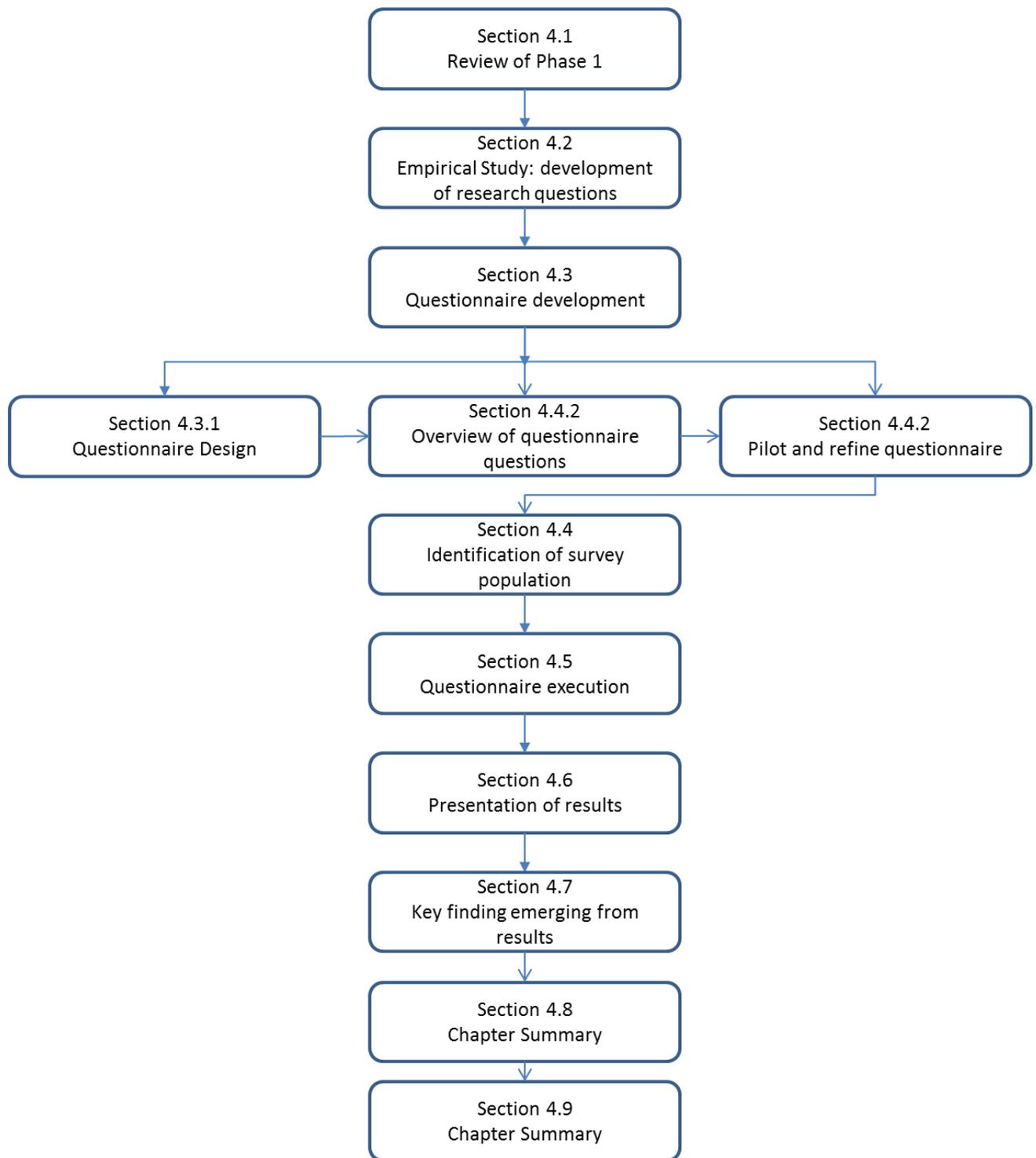
Presented in this chapter is the area of interest, the research problem to be addressed and the programme developed in addressing this problem. It contains the research aim and objectives and a description of a four Phase programme employed in achieving this purpose. Phase one provides a basic understanding of the Lean, the MRO industry and status of the prevalent Lean engagements via literature review and practitioner engagements. Phase 2 delineates the means through which the MRO industry delivers value resulting in the development of the MRO value delivery system (VDS). Phase 3 contains the establishment of the MRO competitive environment and the competitive routes. The role of Lean within each competitive route is also clarified within this phase. Phase 4, brings together the outcome

from Phases 2 and 3 into an approach for Lean application within the aviation MRO industry to enhance competitive advantage and validate them using a case exemplar.

#### 4. EMPIRICAL STUDY INTO THE MRO LEAN STATUS AND APPROACH

This research has so far presented Lean as an approach increasingly being adopted within MRO context to address pertinent challenges. With the overall aim of this research being to present how competitive advantage can be enhanced through successful Lean realisation, it became imperative to first understand the current status of the MRO Lean engagements. To this effect, literature review was carried out (presented in chapter 2) which revealed tangible findings. The other aspect to validating MRO Lean engagement involves actual practitioner engagements. To this effect, this chapter documents the industrial engagement in order to establish the status of the aviation MRO Lean engagement – indeed the state-of-the-art of Lean in aviation MRO.

An empirical study was undertaken which was facilitated by an industry-wide survey. The purpose of this study was to clarify the position as depicted from the available literature review especially in terms of the interpretation of Lean, the focus of its adoption and extent of Lean adoption. The outcome of this study will not only help to clarify the status of MRO Lean engagements but will also inform the area of study which this research seeks to address. Presented in Figure 4.1 is the content breakdown of this chapter.



**Figure 4.1: Table describing contents of the chapter.**

#### 4.1 Phase 1 Review: Motivation for empirical study

The objective of Phase 1 is to establish the status of MRO Lean engagements and indeed the state-of-the-art of Lean in the aviation MRO. Whilst the literature review presented in chapter 2 provided tangible insights into the status of MRO Lean engagements, the available literature were fewer in comparison to manufacturing context (perhaps because of the relatively late introduction of Lean into the MRO industry) and also because, majority of the available literature which directly addressed Lean in aviation MRO were based on specific case studies. Whilst the outcomes of these case studies might be indicative of prevalent MRO Lean engagements, they may not be conclusive. It thus became necessary to engage the industry to validate the findings from literature and subsequently, ensure that the basis and scope of this research has been accurately formed. Based on the overarching goal of Phase 1 of this research and congruent to the literature review carried out, the aim of this industrial engagement remains to “...establish the status of the industry’s Lean engagement...” and as such, not only to understand the position of MRO practitioners with regards to Lean engagements but also to clarify the position delineated from literature about the state-of-the-art of Lean in the aviation MRO industry

In establishing the status of MRO Lean engagements, the literature review sought to understand the interpretation of Lean by the MRO industry, the focus and extent of Lean adoption, the critical success factors and inhibitors of Lean in MRO. The outcome of the literature review did provide some findings which helped to establish the status of MRO Lean engagements.

#### 4.2 Empirical Study: development of research questions.

The study carried out through the empirical study was informed by literature (Chapter 2). The literature review sought to establish the status of MRO Lean engagements by exploring key subjects which include:

- The interpretation of Lean
- The motivation for Lean adoption

- The focus of Lean adoption
- The extent of Lean adoption
- The strategy/approach for Lean engagements
- The critical success factors and enablers for Lean success in MRO context
- The inhibitors for the adoption of Lean adoption.

Analogous to the literature review, the empirical study seeks to further establish the status of MRO Lean engagements which resulted in the following questions:

**Empirical research question 1:** *What is the footprint of your operation?*

This question seeks to understand the nature of the MRO operations. It is the belief of the author that the MRO operations will provide clarity as to the focus of its Lean efforts. It is also the belief of the author that this understanding will provide an indication to the competitive space the MRO is choosing to operate in. This question serves as the foundation in understanding the role of Lean in MRO. Also, understanding of the MRO offering will also provide an insight into the value proposition of the responding organisation. The value proposition will give an indication to the prevailing competitive route of the respondents.

**Empirical research question 2:** *What is nature of Lean engagement?*

This question seeks to identify what Lean tools and techniques have been applied within MRO context to confirm the interpretation of Lean within aviation MRO context.

**Empirical research question 3:** *What is Lean's influence within the context your operational framework?*

This question seeks to understand the awareness and influence of Lean within the characteristics of the MRO operational framework.

**Empirical research question 4:** *What are the results since the introduction of Lean?*

This question seeks to understand the results recorded since the introduction of Lean. A Lean Aerospace Initiative study by MIT<sup>†††</sup> into the auto-industry found that the introduction of Lean led to significant improvement in areas labour hours, production costs, productivity, customer lead times and a scrap/rework. Therefore, investigating these key performance indicators (KPI) of the aviation MRO industry should also provide a similar outcome and thus confirm if Lean is suitable for this context.

The survey questions (questionnaire) will be guided and developed using these empirical research questions.

### 4.3 Questionnaire Development and Methodology

The industry survey was facilitated using a questionnaire on the premise that this approach is an appropriate method by which researchers are able to learn about the characteristics, attitudes or beliefs of a group of people or sample population both large and small (Marshall and Rossman, 1999; Frankfort-Nachmias and Nachmias, 2005).

The process tasks involved in the realisation of this empirical research included the following:

- (a) Design survey questions informed by existing research reported in literature;
- (b) Pilot and refine questionnaire;
- (c) Execute the survey.

#### 4.3.1 Questionnaire Design

In order to solicit definite response from the respondents, the format of the questions were of three forms - close ended, open ended, and contingent questions.

---

<sup>†††</sup>AMT and MIT's lean aerospace initiative to establish lean flight initiative, lean flight initiative aimed at developing and promoting best practices for airline operations, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, 2005, available from <http://www.lean.mit.edu> (access date 13 January 2011) (please note that access to the actual document is restricted to members/member organizations).

With the aim of establishing the extent of Lean adoption within the MRO sector, literature was used to inform the close-ended questions. The respondents were requested to select from a few options. Frankfort-Nachmias and Nachmias, (2005) suggest that there is a danger of introducing bias by giving the respondent a limited options to choose from, and thus, the close-ended questions were followed by open-ended questions. This would allow the respondent to make additional comments or express their own opinions which may have not been adequately captured in the options provided. Finally, where applicable, to ensure that subjectivity was taken into account, the respondents were also asked to put in order of priority through a simple rating process.

A bank of suitable questions which seemed to satisfy the aim of the empirical research were first collected. However, the total number of questions was so many that it risked the danger of respondents being reluctant to answer any question. Thus, the questionnaire was passed through a refinement process with the help of university lecturers, consultants and also industry professionals within the business improvement (Lean) field. The resultant questions that make the questionnaire are explained in Section 4.3.2

#### 4.3.2 Overview of the Questionnaire questions

The questionnaire was divided into two sections with the first section seeking to understand the nature of MRO Lean engagements with regards to the MRO offering (value proposition) as evidenced in their operation footprint. The second section of the questionnaire sought to understand MRO Lean engagements from the perspective its characteristic of MRO operations. As identified in chapter 2, MRO can be described as a ‘product-centric service’ and as such, the characteristics of its operations is represented by its position on services, production and supply chain related activities that the organisation chooses to carry out or have control and ownership (Lewis, 2000).

Full detail of the resultant questionnaire is presented in the Appendix of this thesis; however, the following provides an overview into the reasoning and motivation for each question.

##### Section 1

#### **Q1. What sector does the MRO organisation belongs to?**

This motivation for this question is twofold. First, it seeks to ensure that there was a balanced representation of the all the identified sectors in the survey population (Section 2.4.1).

Secondly, it was indicated in literature review that some MRO organisations may have or are in process of adopting new models - servitization (Section 2.4.3). Whilst it is unsure what effect this would have on the Lean engagements, by identifying the sector the organisation belonged provide the opportunity account for this should the case arise.

**Q2. Indicate which of the following operations are internally carried out within the organisation?**

This question seeks to understand the MRO offering of the respondents. The options provided list all the internal operations that are typical of MRO operations. Mapping the internal operations of the organisation will serve as a good basis in understanding the nature of the Lean engagements.

**Q3. What external services do you offer your customers?**

The motivation for this question seeks to understand the value proposition of the organisation. Whilst the preceding question explores all the activities that are typical of MRO operations, this question seeks to understand what other services are provided by the MRO organisation beyond the typical MRO offering.

**Q4. Which of the following (Lean) initiatives has been applied in your company?**

This question seeks to identify the actual Lean engagement and or continuous improvement profile of the responding organisation. The options provided list Lean and other approaches (for example, Agile, Six Sigma) which may be argued are distinct from the Lean. Answers to this question will validate the finding as to the perception/interpretation of Lean as being viable in MRO context albeit not sufficient by itself to address pertinent MRO challenges.

**Q5. Indicate where the most benefit has been witnessed due to the introduction of Lean?**

This questions seeks to reveal the success of Lean and where this success has been mostly recorded. The options provided are similar to the results from the MIT (2005) survey that advocates the application of Lean in the aviation sector. The answers to this question will also

indicate how the introduction of Lean (or alternates) has improved the competitive position of the organisation particularly with regards to turn-around-time (TAT).

## **Section 2:**

With literature suggesting that the focus of Lean implementation was directed towards waste reduction, this section sought to explore where exactly the Lean efforts have been concerted within all of its operations. The characteristics of operation (explained in more detail in chapter 5) are delineated into the *structural* and *infrastructural* categories which are representative of the organisations position on not only the production activities but also its services and supply chain related activities.

Unlike Section 1, this section lists out all the characteristics of operation and requests that the respondents indicate how successful Lean has been within the each of the characteristics of operation. It is belief that the success of Lean not only provides an indication of the status of Lean engagements but also provides an insight into the interpretation (perception), extent and approach (strategy) towards their Lean engagements.

**Q6. Operational systems are general classified into the following characteristics. Please indicate how successful Lean tool and techniques has been in these areas.**

Finally, the respondents were asked to identify the characteristic that they were most ‘proud’ off. It is the believe of the author that the response to this question is indicative of the success of Lean within the characteristics of operation but more importantly, it is indicative of where the key problems area lie and how Lean has influenced those areas i.e. the challenges (motivation) that necessitated Lean engagements which has now witnessed improvement since Lean’s application. These areas will provide an insight to the challenges facing MRO and contribute to the knowledge on the enablers and threats to MRO competitiveness.

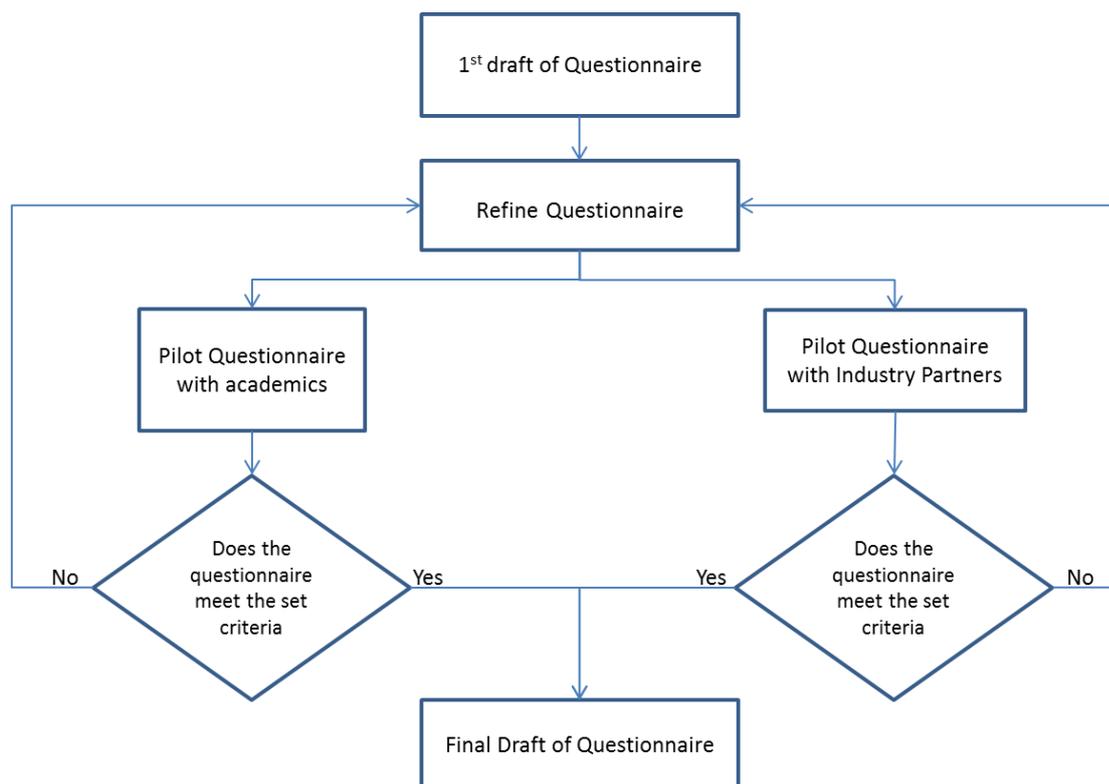
It is worth noting that the responses to these questions are subjective and are based on the opinions of industry leaders. However, responses to the above questions synthesised with literature review will provide a basis from which safe judgments can be made.

### 4.3.3 Pilot and Refine Questionnaire

For completeness, the designed questionnaire was subjected to both academic and industrial review to ensure that it met the following criteria:

1. Are the research questions comprehensive and consistent with the research aim and objectives?
2. Is the language and the tone chosen clear removing all ambiguity?
3. Is it simple and easy to complete mitigating inhibitions from respondents?

There were three phases to the refinement process. From the bank of suitable questions which seemed to satisfy the aim of the empirical research, the first phase of refinement involved grouping these questions in accordance with empirical research questions in Section 4.2. The second Phase involved critical analyses of the questions within each group to ensure that only questions that offered direct relevance to the aim of the empirical research were left. With the questionnaire being used as a tool to get obtain more clarity on a few pertinent issues, it was crucial to keep the tone of the questions neutral and this comprised the final stage of the refining process. Figure 4.2 provides an overview of the refinement steps for the questionnaire



**Figure 4.2: Industrial and academic review of the questionnaire via an iterative pilot process.**

The survey was submitted to lecturers at Cranfield University, industrial partners (Lufthansa and Gulfstream) and also to fellow colleagues at Cranfield University and the University of Hertfordshire. Responses from the pilot groups were discussed with each group to fully understand their advice and suggestions before the refinement of the questionnaire. This iterative process took a total of three months to refine the questionnaire into the finished product of a total of 7 broad questions with a variety of options in each question which the respondents are able to choose from.

Section one sought to identify the production footprint of the responding organisation both in terms of what sector the belonged to within the MRO industry and also what capabilities the company was directly responsible for. This section was to ensure that the survey covered all sectors of the industry and provided a context within which the extent of Lean adoption can be established. Once the context has been set, it then went on to explore and identify what type of Lean tools and techniques have been implemented within these organisations. This is predicated on the understanding that the nature of the tools and techniques employed will give an insight into the focus and the overall approach to Lean by these organisations. The second section sought to understand the MRO business environment and the influence of Lean within this context. This section also sought to understand the areas that were more influenced by Lean since its introduction. It is the believe of the researcher that syntheses of all the responses to the questionnaire will clarify the position delineated from literature into the state-of-the-art of Lean and also provide more insight into context of application and the MRO business environment.

#### 4.4 Identification of the Population to be Surveyed

The survey population to be considered for this empirical study has to take into account all the different illustrations and classifications of the MRO industry which was established in chapter 2 of this thesis. The survey was aimed at all the sectors of the MRO industry to avoid any bias (Crute et al., 2003; Pettersen, 2009). Thus, in seeking to identify a target population, it was essential that the review of available databases took this into consideration such that all arms of the MRO industry, types (based on type-function) and different forms of organisational structure were dully represented. Thus, information such as company activities, offerings, location, size and revenue were used as criteria in identifying the survey population. The main data-source was the Forecasting Analysis & Modelling Environment

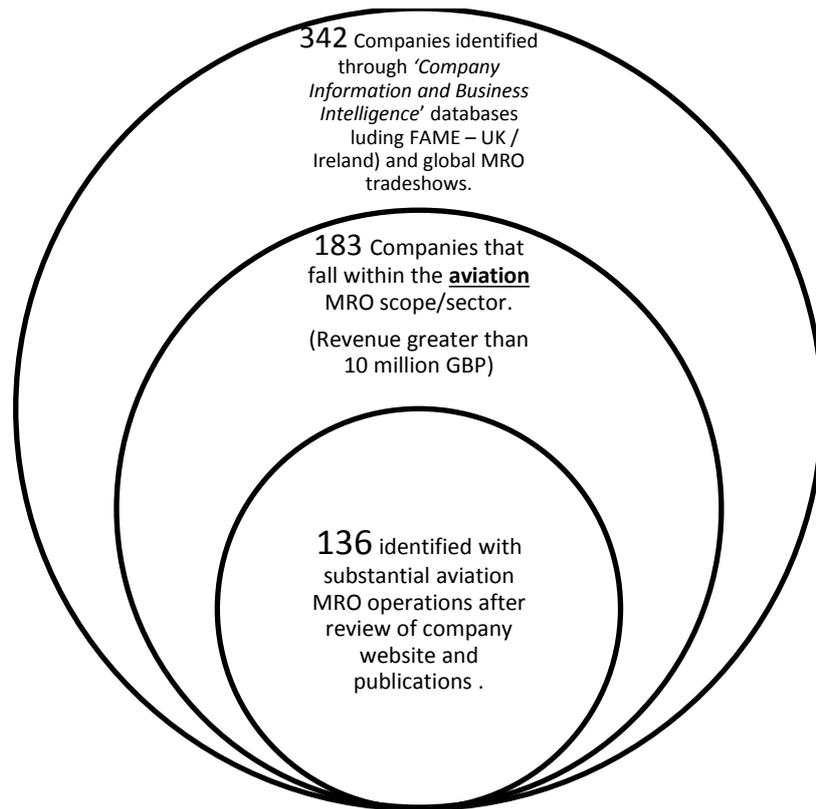
(FAME) was used for the identification of the survey population. This platform provided the information such as activities of the company, the company size and turnover, the ownership and location of the organisation. This approach to the identification of the survey population was supported by organisations identified through the International MRO Trade shows (UK 2010) and from the Aviation Weekly MRO database.

However, it was important to ensure that the identified companies had the necessary Part 145 Approval for them to be classed as an MRO organisation. This approval was verified from the UK Civil Aviation Authority (CAA) Website<sup>\*\*\*</sup>. 342 companies were identified from both the FAME database and organisations with Part 145 approval. However, it was noted through a sample website review that some of the organisations with Part 145 approval did not have MRO as the core of their operations. The next step in the identification of sample population involved a financial review of the organisation to identify organisations which although did not have a MRO as central to their operations, had a revenue of over 10 million GBP (or equivalent) attributed to its MRO. Whilst the 10 million GBP serves as a substantial enough to identify the organisations with MRO activities, it was difficult to isolate the MRO footprint from their other activities and as such, the next step in identifying the survey sample was to identify organisations whose main offering was MRO. This led to the identification of 136 companies. The survey was then carried out using this identified sample. Figure 4.3 shows the breakdown of how the survey sample was identified. Within this survey sample, the breakdown according to the sector they belong is also presented in Table 4.1. Whilst this distribution was not even spread, it was deemed by the author that each sector had enough representation to prevent against bias or skewed results.

---

<sup>\*\*\*</sup> List of Part 145 Approved companies:

<http://www.caa.co.uk/workarea/DownloadAsset.aspx?id=4294978114>



**Figure 4.3: Spread of companies identified for the empirical (survey) study.**

Engine	Heavy Maintenance Visits	Component	Line Maintenance	Avionics	Modifications and Retro-fits
23	17	35	26	19	16
<b>Total number of companies identified for the survey = 136</b>					

**Table 4.1: Breakdown of the companies identified for the survey according to the MRO sector they belong to.**

#### 4.5 Questionnaire Execution

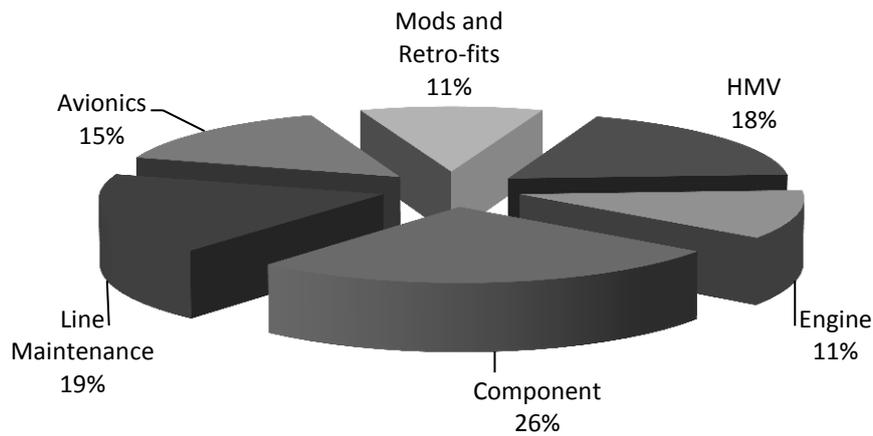
On completion of the questionnaire design (inclusive of the refinement process), the questionnaire was sent to the identified companies. They were sent by post and addressed to senior executives within such organisations particularly the Production Manager, Head of

operations or the Managing Directors. The execution of the survey was timed to happen between the months of February to July 2010. This window during the calendar year was agreed upon to ensure that the responses were received before the summer months during which most workforce tend to go on holidays. These dates provided the window for maximum response rate. Follow up calls were made three weeks after distribution to ascertain that the questionnaire had been received. Care was taken to ensure that the contents of any discussion did not bias the outcome.

#### 4.6 Presentation of Results

The original target sample was 136 companies with 22 fully completed questionnaires received in return. The response rate as calculated by the American Association of Public Opinion Poll Research was approximately 16 per cent. The critical evaluation of the responses confirmed initial literature review findings and provided significant insights into the perception of Lean within the Aviation MRO community.

The first question of the survey thus was to understand identify the MRO sector the respondent organisation belonged to. This resulted in the spread represented in Figure 4.4 with the most respondent from the Component Sector (26%) and the least represented sectors were Modification and Retrofits; and Engine Sector (11% each). The difference between the most and least represented sectors had negligible effect on what the survey was aimed at achieving. Other contextual factors that further reveal the nature of the MRO organisation which the authors believe will serve as a clearer indicator of the focus, motivation and approach towards Lean realisation were also included in the survey.



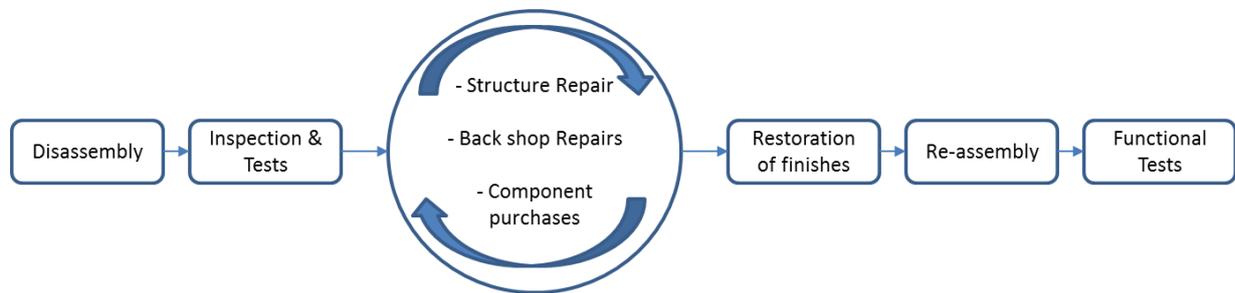
**Figure 4.4: Survey response according to industry sector: Heavy Maintenance Visit (HMV); Engine Overhaul; Component Overhaul; Line Maintenance; Avionics; Major Modifications, Retrofits and Conversions.**

#### 4.7 Key Findings Emerging from Survey Results

The first question the empirical study (Section 4.2) sought to answer was to identify what the operation footprint of the MRO organisation. The motivation for this was to more accurately understand the respondents Lean engagements within the context of the overall service (value) provided ranging from the internal MRO activities to the after event support care provided to the customer. Also, with a few Lean authors (Crute et al., (2003); Shah and Ward (2003); Pettersen (2009)) suggesting that Lean programmes are plant specific, it was necessary to identify the production footprint of the responding organisation. The first three questions of the survey were aimed at answering this. By comparing the internal MRO activities to the external services provided, the operation footprint of an organisation is mapped. The operation footprint is indicative of the respondent's status within the MRO competitive space.

Typical internal MRO operations as observed by the author (within the Lufthansa Technik MRO), can be broadly divided onto the following process steps as shown in Figure 4.5. Whilst the flow may not always be in this order, typical MRO process steps include: Disassembly;

Inspection and Tests, Repair or Rework of sub-assemblies or piece-part; Restoration of surface finishes (e.g. Paint), Build Up or re-assembly and Functional test.



**Figure 4.5: Overview of typical MRO operations.**

Typical external operations apart from aircraft-on-ground (AOG) or On-wing Service (OWS) are comprised of every additional service that could be provided to the customer. Whilst the permutations of this external service could be endless, aftercare services typical of product-centric service environments include: System Integration, Consulting or Product Training. As with most of the question, the option was provided to the respondent to list additional activities that are not included in the provided options.

Analysis of the results showed that there was significantly more emphasis on the internally carried out operations as compared with external services provided to the customer. Whilst the emphasis on the internal carried operations is not surprising, this outcome is indicative of the MRO focus. Figure 4.6 to Figure 4.11 show the relationship between the internally carried out operations to the external carried out operations for each MRO sector.

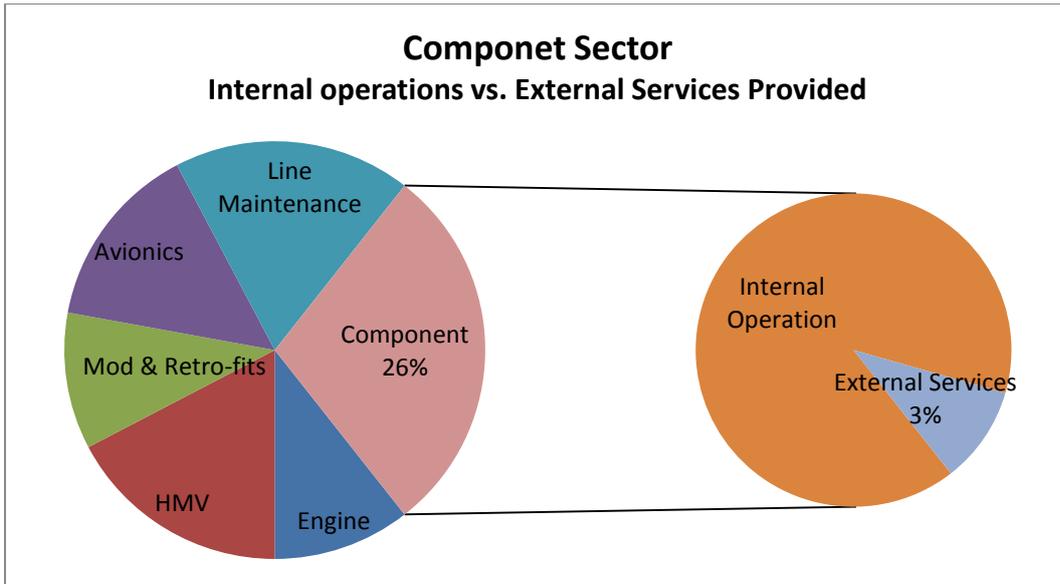


Figure 4.6: MRO Offering – Operation footprint (Component Sector).

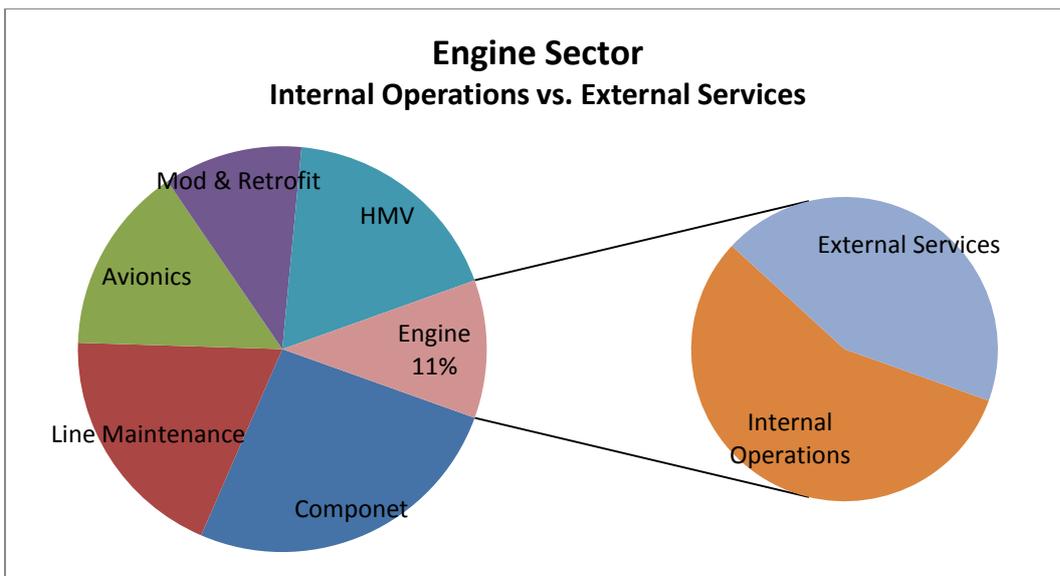


Figure 4.7: MRO Offering – Operation Footprint – Engine Sector.

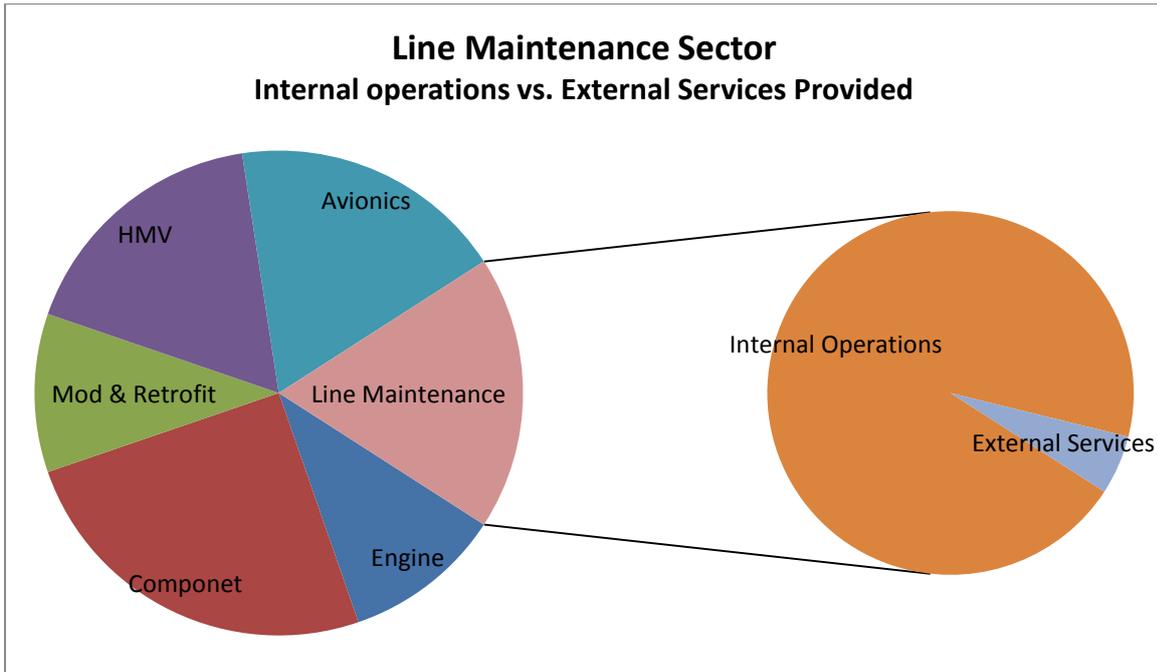


Figure 4.8: MRO Offering – Operation footprint (Line Maintenance).

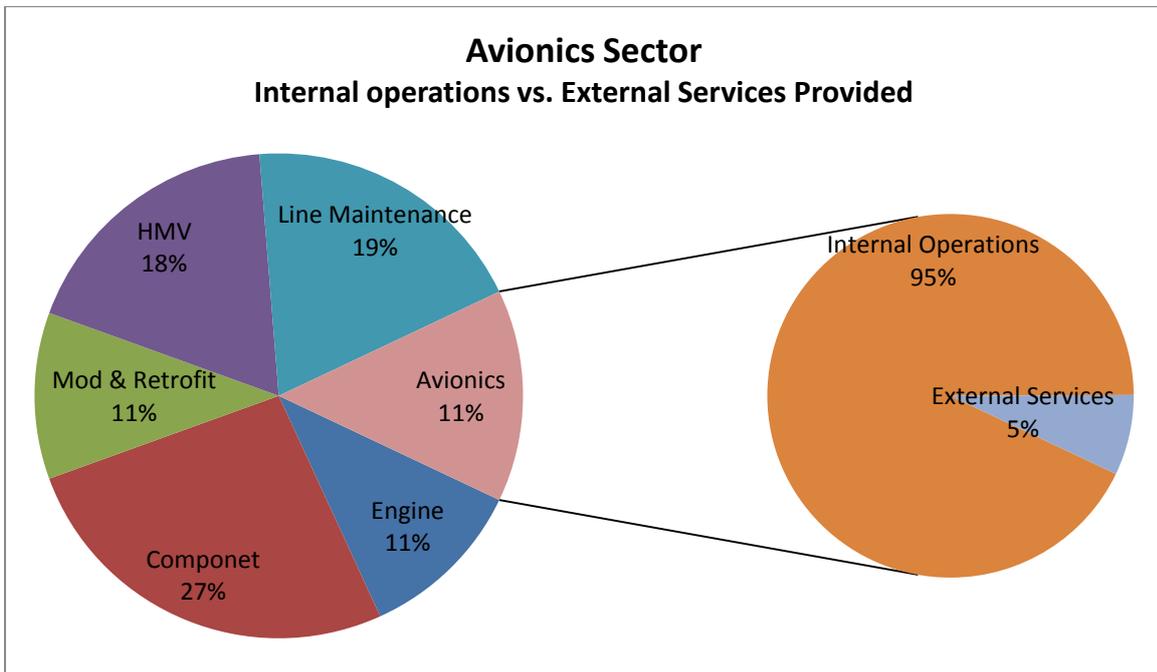


Figure 4.9: MRO Offering – Operation footprint (Avionics).

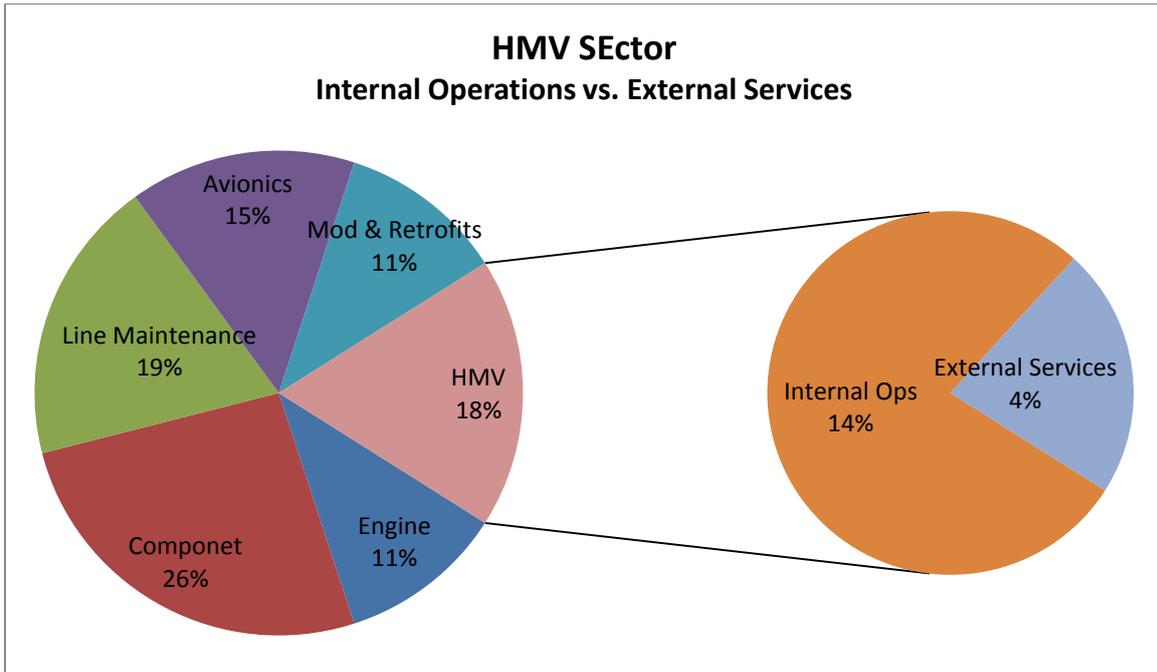


Figure 4.10: MRO Offering – Operation footprint (HMV Sector).

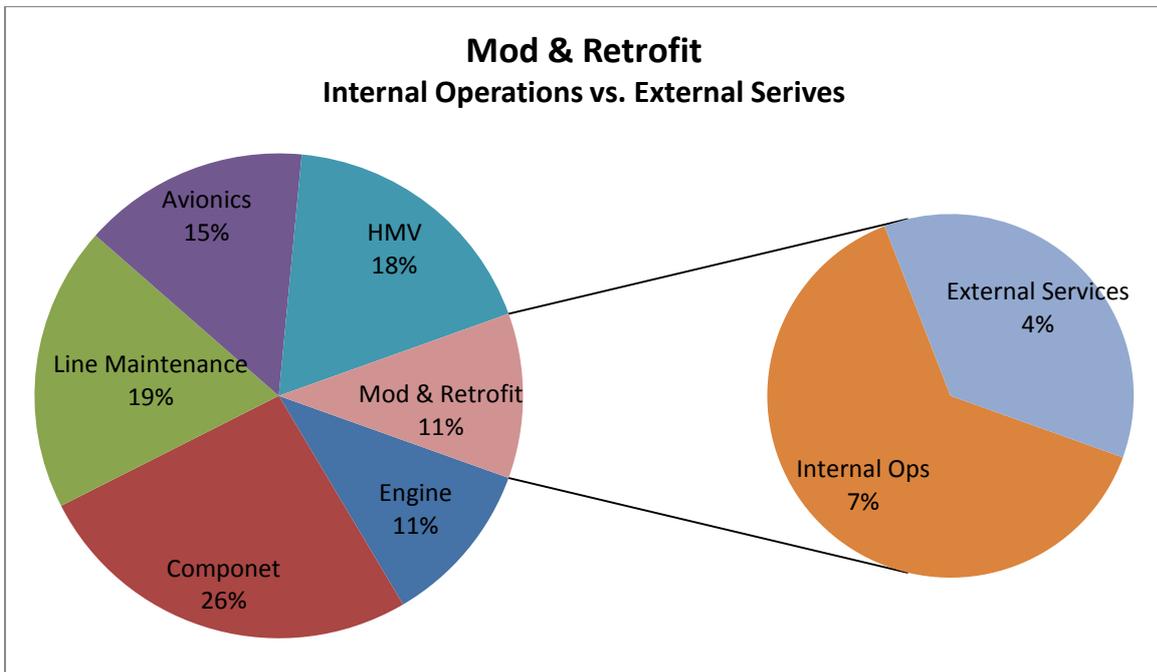


Figure 4.11: MRO Offering – Operation footprint (Mod & Retrofits).

However, it was observed that the Engine sector provided significantly more external services to the customer (See Figure 4.7). As mentioned in chapter 2 (Section 2.4.3), the effect

of *servitization* and increase in OEM entering into the MRO market may be a contributor for noted increase in External services provided by MRO firms within the MRO engine sector.

With the general focus of MRO operations more internally inclined, it safe to infer that the nature of their Lean engagements will be similarly focused. As such, the prevalent application of Lean with regards to the competitive advantage will be centred on doing more with less i.e. waste reductions. Srinivasan et al., (2014) suggest that viewing Lean as tool to remove waste is limiting and narrow minded because it could facilitate a tendency of improvements at local process steps which may have little or no effect on the organisation's performance. This outcome is consistent with [Finding 3](#) from Literature review (chapter 2) and has led the author to conclude that:

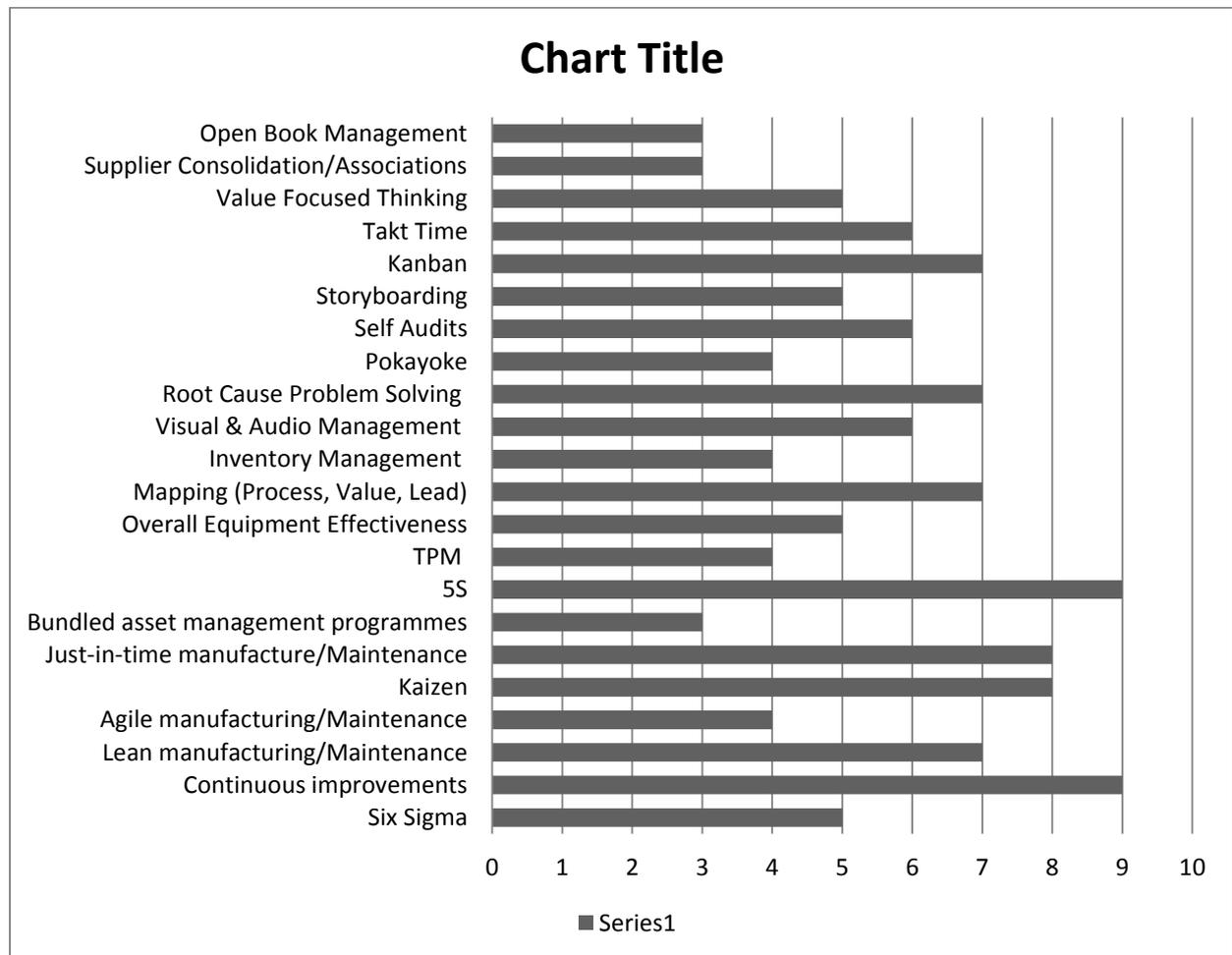
#### Finding 1

Prevalent MRO operation footprint is more inclined towards its in-house production activities and as such, there is a high tendency for Lean to be viewed and interpreted purely as a waste reduction tool.

Upon the clarity of the operation footprint realised, the next motivation of the empirical study is to understand the nature of the Lean engagements. One way of achieving is by identifying the Lean tools that have been applied within MRO. A list of Lean tools was provided in the questionnaire from which the respondents were to select from. But also, the respondents were also provided with an option to write other tools and practices which have been employed but not on the list.

Srinivasan et al., (2014) suggests that not all Lean tools are applicable within MRO context (at least, without adaptation) and as such, the type of tools that have been employed will be indicative of the nature of their Lean engagements. **Tools such as Takt time, 5S, Mistake proofing (Pokayoke) are tools that can be directly applied within MRO context.** Analysis of the responses as presented in Figure 4.12 shows the tools and practices that have been applied within MRO. The tools that have been most applied include Just-In-Time (JIT), 5S and Takt time. Other practices such as Continuous Improvement and Six Sigma were also among the top ranking practices that have been applied. Comparing the most popular Lean tools from

the results (over fifty percentile) with the tools that Srinivasan et al., (2014) propose to be appropriate within MRO suggest the nature of Lean engagements to be



**Figure 4.12: The spread of the type of tools adopted by the MRO industry.**

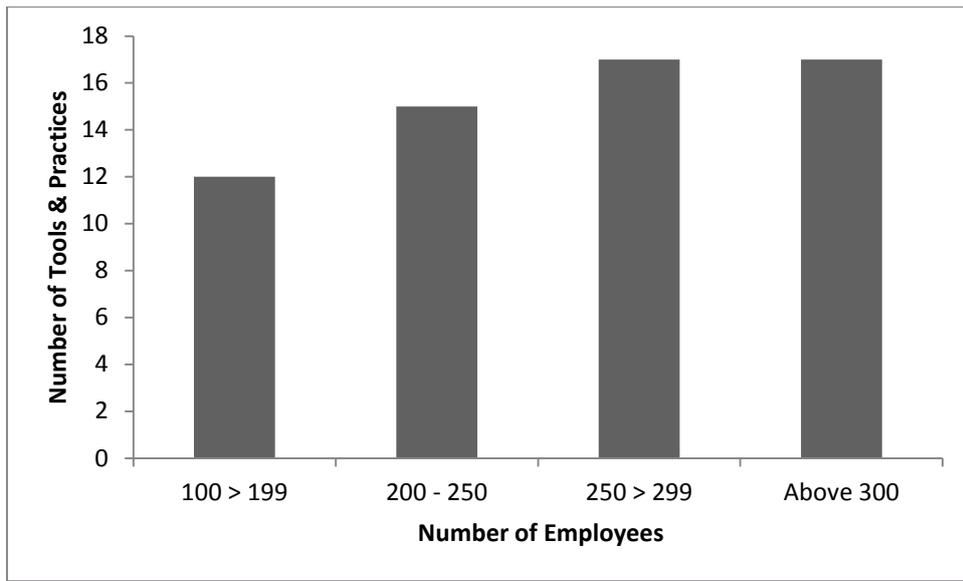
However, similar to Finding 1 from the literature review (Chapter 2), it was also observed that other practices such as Six Sigma and Agile Manufacturing have also been applied along with the Lean tools. This confirms the finding from literature that Lean albeit seen as a viable approach MRO context, by itself, Lean is not sufficient to realise company goals. This outcome suggests either a limitation with Lean itself or a lack understanding of Lean and how to employ it within MRO context. The latter seems to be the case as especially with a significant number of the respondents indicating implementing JIT programmes, but only a few alluded to applying inventory control measures. This is contradictory because literature review suggests that effective JIT implementation is associated with inventory reduction (Balakrishnan et al., 1996; Sakakibara et al., 1997; Boute et al., 2004 and Kros et al., 2006)

Notwithstanding, the targets of Lean tools are to be used to reduce flow time, reduce inventory and create additional capacity. It was evident from the results that tools such as 5S have been widely applied. This perhaps is because 5S is referred to as the foundation upon which all other Lean business improvement initiatives are established on. ‘5S’ process is a simple methodical team based approach to organising work space to ensure that it is tidy, arranged ergonomically, efficient and capable of repeatable, quality output. Successful 5S implementation contributes to significant reductions in the 7 wastes identified by Ohno (1988) as unnecessary clutter is removed from the working environment and tools and equipment necessary to carry-out tasks are located in the most ergonomic locations. Effective 5S implementation also makes all malfunctions in the production process more obvious so that corrective actions are prompt. Thus, the nature of MRO Lean engagements assessed based on the tools and practices that have been applied leads the author to come to a similar conclusion as Finding 1 that:

#### Finding 2

MRO Lean engagements have resulted in the application of several Lean tools and practices; however, clarity is still needed in how to adapt Lean to the MRO context.

Whilst comparing the number of tools and practices applied by an organisation may not be commiserate to the level of success, it was interesting to observe from the responses that organisation with more employees (as checked from company website), irrespective of their operation footprint (presented earlier), were more receptive overall to the adoption of Lean. This was evidenced in the number of Lean practices they had adopted as presented in Figure 4.13. This is consistent with the work of Shah and Ward (2003) who suggest that the reason larger organisations are more receptive to the that adoption of Lean practices is because they possess both capital and human resources that facilitate adoption and implementation of Lean practices as well as returns on investments associated with Lean adoption (White et al., 1999).



**Figure 4.13: Graph showing the relationship between the number of Tools & Practices applied with the number of employees in the company.**

Although the responses showed very positive indication of Lean adoption within the aviation MRO industry, the increased emphasis on their internal operations raises a danger of Lean being predominantly directed towards addressing activities akin with manufacturing particularly to address *process variation* issues. However, as identified from literature, the MRO context is characterised by both *process variation* and *work scope variation* challenges (Chapter 2 Section 2.6), and as such, Lean’s success within this context will be necessitate first understanding the distinction between the two and correctly appropriating Lean solutions to address them.

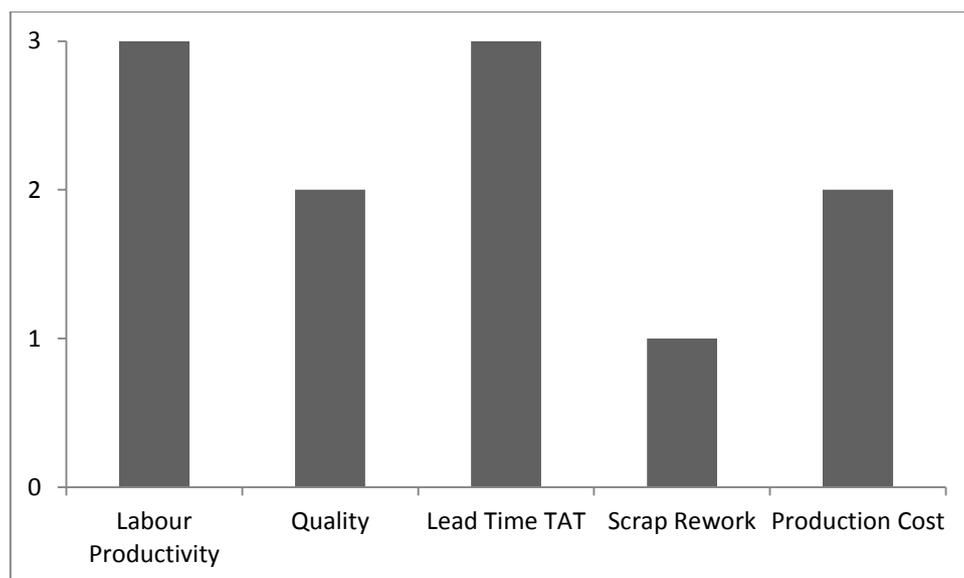
Conversely, these observations also suggest that the increased focus on internal (shopfloor) activities may be indicative of the Lean directive when MRO is viewed through the lens of “*product-centric service*” description (Chapter 2, Section 2.4.3). The product-centric service view describes MRO as a combination of *manufacturing-type* and *service-type* characteristics and as such, not only is there a danger of Lean being purely directed towards process variation issues (due to its manufacturing similarities) but also, this view could be limiting in that it may not consider the *service-type* aspect of MRO. The lower focus on external activities as evidenced from the production footprints earlier presented supports this observation. Although authors like Chandler (1962) and Child (1972) suggests that the effective integration of service orientated activities within an organisation may be complicated, more recent publications perceive the integration of services into the operations

footprint as a competitive necessity (Wise and Baumgartner, 1999; Oliva and Kallenberg, 2003; Baines et al., 2009). With literature suggesting that competitive advantage is significantly enhanced by becoming more active in the service-related activities, it could be inferred from this study that the predominant application of Lean to address manufacturing-like activities may be limiting and this has led the author to conclude that:

### Finding 3

The nature of MRO Lean engagements is not holistic in its realisation to facilitate competitive advantage.

One of the hypothesis that informed this empirical study (Section 4.2) is based on the assumption that if the allusions to adoption of Lean in MRO are accurate, then the successes recorded by the MRO industry should be consistent with what Lean can deliver. This assumption was tested in the survey by asking the respondents to provide a rating of their performance improvements. As presented in Figure 4.14, it was observed from the responses that there were improvements in key areas ranging from Labour productivity to Production cost. However, the areas that had recorded the most improvement were improvements in *Turn-Around-Time (TAT)* and *Labour Productivity*.



**Figure 4.14: The outcome of Lean implementation within generic key performance measuring areas**

This is consistent with the report published by MIT<sup>§§§</sup> (2005), which indicated that the introduction of Lean resulted in approximately a 10-71 percent improvement in labour hours; a 27-100 percent improvement in productivity and 16-50 percent improvement in customer lead time. Although it could not be established the exact percentage increase in improvement, the analyses of the results indicated strong improvement in these two areas – *Labour Productivity* and reduction in *TAT*.

A medium-positive indication was given in other areas such as the improvement in *Quality* and *Production Cost*. It is important to point out that with *Quality* considered as a market qualifier and not an order-winning option in the aviation industry; it is a positive observation to note from the results that the implementation of Lean in the MRO industry has not compromised product quality. Womack et al. (1990) suggests that most efficient production operations have introduced Lean principles where quality is focused on achieving product conformance and the minimisation of waste in materials and resource usage. However, with the '*Rework/Scrap cost*' not performing as well as other key indicators, one can safely deduce that although the adoption of Lean in the MRO industry highlighted better product conformance, significant improvements are yet to be made on the minimisation of materials and resource wastes.

Whilst the outcome of Lean introduction has led to improvement TAT, other challenges which are characteristic of MRO such as demand variability, complex and unpredictable (repair) flow paths, unpredictable supplier response times and shared resource management still need to be addressed. The relatively lower success rating recorded in *Production Cost* and *Scrap / Rework* suggest that a benefit of Lean witnessed in improved TAT is at a relative expensive cost. As such, it is possible that whilst these improvements may have met customer's expectations, it may not necessarily translate into (financial) profits or even or competitive advantage. As similarly identified from literature review (Chapter 2, Finding 8) incorrectly appropriating Lean due to a lack of understanding of the characteristics of the

---

1. <sup>§§§</sup> Massachusetts Institute of Technology (MIT), Lean Aerospace Initiative (2005), available at: [www.lean.mit.edu](http://www.lean.mit.edu) (assessed January, 2011).

MRO industry may result in outcomes that will hinder the advancement of Lean in the MRO industry. Whilst the overall outcome is positive, this has led to author to conclude that:

#### Finding 4

The outcome of MRO Lean engagement albeit positive still requires clarification as to how to appropriate its application to facilitate competitive advantage.

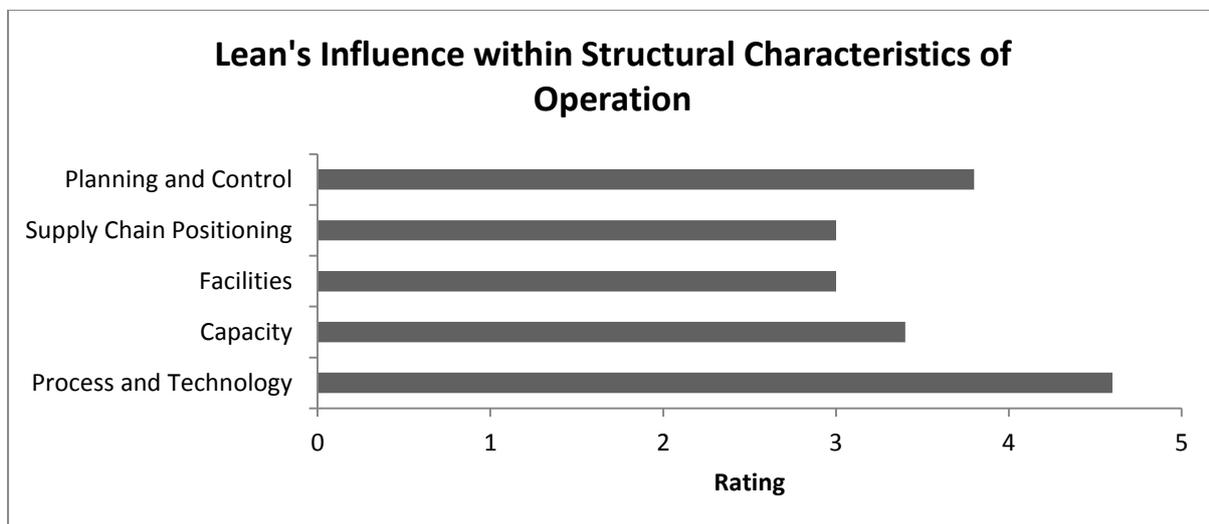
Guided by the product-centric service description of MRO, the extent of Lean adoption within the MRO was further explored within the context of its characteristics of operation. The characteristic of operation considers not only the transactional (manufacture or production) activities but also the relational (service) activities of operation and understanding the influence of Lean within this context will provide a clearer picture of MRO Lean's engagement. Using the Baines et al., (2009) operational framework for product-centric-service type organisations, the respondents were asked to profile the influence of Lean within each characteristic of operation. The respondents answers to each of the questions will not only help to profile the influence of Lean within each area but will also help in providing more insight as to whether the proposed framework is sufficient in describing the dimension to MRO operations. As presented in Table 4.2, this framework is divided into two aspects: Structural characteristics of operation and infra-structural characteristics of operation. The structural aspect is comprised of the transactional aspects whilst the infra-structural aspect is comprised of the relational aspects. (Further details of this framework are described in Chapter 5 of this thesis).

<b>Structural characteristics</b>	<b>Infra-structural characteristics</b>
Process and Technology	Human Resources
Capacity	Quality control
Facilities	New Product/Service Range and introduction
Supply Chain Positioning	Performance measurement
Planning and Control	Supplier Relations
	Customer Relations

**Table 4.2: Characteristics of operation (Baines et al., 2009)**

#### 4.7.1 Structural Characteristics

Within the structural characteristics of operation, analysis of the responses indicates that Lean efforts have been most directed towards the ‘*Process & Technology*’ characteristic of operation as shown in Figure 4.15. This strategic business decision area deals with the interaction between physical resources and the technology employed and thus, its parameters are more closely linked to conventional manufacturing environments (Hayes & Wheelwright, (1984); Hill, (2000)). This would involve the use of automated systems to enhance product conformance, efficiency, communication and customer interaction. The optimisation of the shopfloor layout to get the best out of these automated systems is also covered in this characteristic of operation (Mills et al., (1996); Bowen & William, (1998)).



**Figure 4.15: Graph showing the rating of Lean’s influence within MRO Structural characteristics of operation**

The extensive research that has been carried out within this characteristic of operation in the manufacturing sector provides substantial information that can aid the advancement of Lean within MRO. The outcome of Lean within this characteristic of operation is consistent with and supports previous observations and findings. However, caution has to be taken in the transference of Lean from a conventional manufacturing shopfloor to an MRO shopfloor as they are different. The stochastic nature of MRO repair and rework is the fundamental difference between the two environments. Also, while Lean in manufacturing environments encourages single-piece flow, it is not unusual to find batching of parts with similar pertinent process requirements in MRO environment so as to benefit from combined set-up time reduction. Consequentially, this will add to the need to improve process flow which will

necessitate a re-evaluation of the shopfloor layout possibly based on part groups, families, or process requirements. As such, '*Planning and Control*' characteristic of operation becomes a key area in MRO operation.

*Planning and Control* characteristic of operation has to do with the optimisation of product availability and interaction between information capacity and stock (Ranky, 1983; Hill, 2000). Literature suggests that production *Planning and Control* activities are inherently more complex within MRO-type environments (Guide, 2000). MRO *Planning and Control* is all the more complex due to market fluctuations (external), unknown and stochastic condition of products (internal). Thus, the popularity of more advanced production planning tools that focus on the optimisation of product availability and interaction between information capacity and stock such as Enterprise Resource Planning (ERP), Materials Requirements Planning (MRP), to simple tools (Kanban Systems) are prevalent. The systems within *Process and Technology* are closely linked applications within *Planning and Control* and as such, it is safe to say that the influence of Lean within the *Process and Technology* characteristic of operation will also have an effect within the *Planning and Control* characteristic of operation. However, it should be noted as shown in Figure 4.15 that the rating of Lean in *Planning and Control* is still somewhat lagging behind the *Process and Technology* suggesting that efficient balance between product availability, information capacity and stock is still yet to be reached.

The influence of Lean within the '*Capacity*' characteristic of operation was also noted to be positive. *Capacity* characteristic of operation deals with the interaction between 'demand', 'supply' and 'utilisation of resources' and this survey result suggest that MRO organisations are finding relative success in the application of Lean to balance these three parameters. Although literature suggests that this balance is much easier to reach in conventional manufacturing context, it is more complex in MRO-type environments (Hayes & Wheelwright, (1984); Baines *et al.*, (2009)). A requirement of MRO offering is the ability to meet unscheduled maintenance demand. These unscheduled demands could vary from minor line maintenance input to critical situations where an aircraft due for imminent operation is grounded for immediate hanger or on-wing maintenance support. The incorporation of these unscheduled demands into the production schedule will affect the utilisation of resources which will also be reflected in the inventory levels held by the organisation (in most cases).

Harmonising all of these factors within this characteristic of operation will determine the *Capacity* status of the organisation.

Conversely, the application of Lean in the *Facility* and *Supply Chain* operation recorded relatively lower ratings as compared with other structural areas. The *Facility* decision area involves the proximity of the organisation to customers, suppliers and markets (Baines et al., 2009). This characteristic of operation also influences the human resources, skills information and possibly finance that are available to the organisation. More importantly, this characteristic of operation is critical in delivering quick customer support which is often needed. With more global MRO support increasingly becoming a necessity for airline operators, the need to adapt to this evolving demand is an increasing necessity for survival and competitiveness. Current industry practice is that the global support required by the airline operators is still being expedited from locations far away from the customer and the suppliers. Problem troubleshooting and resolution from distant locations do not support the effective and quick response to changes in the information from the market (Goldman et al., 1995) and could significantly hamper organisational growth. Subsequently, the ability to rapidly reconfigure the production process to meet both external (market, customer demands) and internal (production demands) is significantly hampered.

Similarly, the strategic position of the organisation along the supply chain plays an important role in meeting agreed customer commitments (Naylor et al., 1999). The goal of an integrated supply chain is to remove all boundaries to ease the flow of material, cash, resources and information. Although improvements have been recorded especially in dealing with the stochastic nature inherent of MRO production, the relatively low score within the *Supply Chain* characteristic of operation could serve as an inhibitor in Lean's ability in meeting the business demands. This will inevitably result in longer TAT which compromises one of the main objectives for Lean introduction in the first place.

The relatively lower rating of Lean in the *Facility* characteristic of operation is also reflected in the low outcome of Lean on the *Supply Chain Positioning* characteristic of operation. A few organisations have addressed the application of Lean in the *Facility* and *Supply Chain Positioning* business decision areas. For example, business approaches like TotalCare by Rolls-Royce involved major restructuring of their business in order to effectively meet changing demands of the global aviation industry (Tiwari, 2005). Not only has this

restructuring generated commendable profits and new revenue streams, these organisations have been able to expedite prompt on-wing and shop assistance to customers globally and thus enhancing customer experience and satisfaction. By consolidating duplicated supply chains and aligning support network through intelligent data capture, they have managed to drive more efficient services to the customer (Ryals, 2010). Although it would take tremendous amount of effort to reach this stage, the benefits both in commercial and customer satisfaction terms are undeniable (Tiwari, 2005). Thus, the role of Lean within these areas (*Facility and Supply Chain positioning*) is not simply the application of off-the-shelf Lean tools that may have been copied from manufacturing (without adaption to the new context) but more so the Lean *thinking* which informs business strategy.

The influence of Lean across all aspects of the structural characteristics provides a picture that is consistent with previous findings. The influence of Lean is observed to be relatively higher in structural areas where Lean tools can be more readily applied to (*Process and Technology; Planning Control and Capacity*). However, in structural characteristics where more Lean *thinking* is needed to inform strategy of the business (Facility and Supply chain Positioning), the influence of Lean is relatively lower. This has led the author to conclude that:

#### Finding 5

The proliferation of Lean within the transactional aspects of MRO operations is positive; although this outcome has more Lean tools and practices based than Lean thinking based.

As a secondary observation from the analyses of the responses, casual linkages could be drawn on the influence of Lean within the structural characteristics of operation. The interaction between the *Process and Technology, Planning and Control; Capacity* characteristics of operation may have facilitated the proliferation of Lean within these areas. This relationship is based on the observation that the successful application of Lean in addressing physical resources and technologies that are used within operation, would invariable be reflected in the decisions made with regards to the flow of materials through the company and hence, the balance between these two areas of operation represented in the *Capacity* characteristics of operation. Similarly, the interaction between the *Supply Chain*

*Positioning* and the *Facility* characteristic of operation may also be a factor in the proliferation of Lean within these areas. This is because the position of the company with regards to its supply chain activities significantly determines the organisation's ability to expedite flexible and agile support to the customer especially on a global scale. As such, it could be postulated that the influence of Lean within these areas is proportional to the interactions between the characteristics of operation. Several permutations of the interaction between these characteristics of operation would also reveal other outcomes; however, the most dominant of these relationships as observed from this empirical study are as briefly explained. These relationships can be expressed mathematically in terms of:

$$\text{Lean influence (SCO): } PT \propto PC \propto Cap$$

And

$$\text{Lean influence (SCO): } SCP \propto Fac$$

Where

SCO = Structural Characteristics of Operation

PT = Process and Technology

PC = Planning and Control

Cap = Capacity

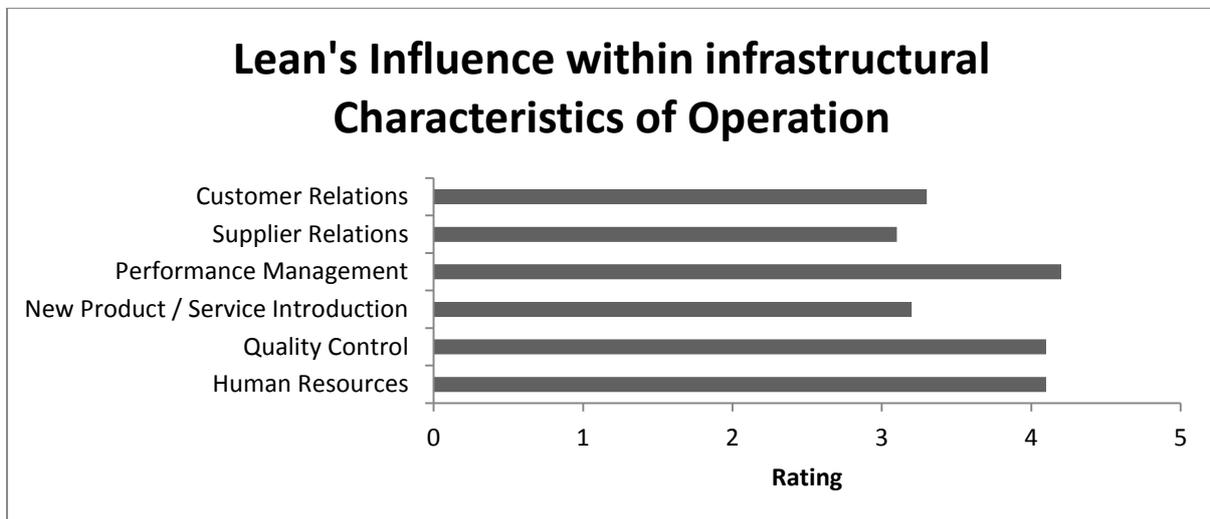
SCP = Supply Chain Positioning

Fac = Facility

Although these relationships are inductive, they capture the approach of the MRO industry towards the adoption of Lean in aviation MRO context. The areas that seem to exhibit more positive emphasis are focused on the in-house production requirements of the organisation in terms of the shop-floor optimisation. However, the production requirement of the MRO industry extends beyond the interaction of these characteristics internally, but also encapsulates external factors that include its position on its supply chain activities in order to provide flexible and agile customer support.

#### 4.7.2 Infra-structural characteristics:

The infra-structural characteristics of operation refer to the *relational* aspects of MRO operations that focuses on the interaction of the non-physical systems connected by similar value propositions as the production operations (Baines et al., 2009). As already established by Karlsson and Ahlstrom (1996), a company does not achieve Lean product development simply by implementing Lean techniques to the physical operations alone, instead, a successful move towards Lean requires approaching these interrelated systems in a coherent way. Successful Lean implementation will require addressing both the physical and the non-physical systems. Indeed, this is one of the core ideals of successful Lean implementation programmes. The analysis of the responses for the influence of Lean within the infra-structural characteristics of operations is as presented in Figure 4.16.



**Figure 4.16:** Graph showing the rating of Lean’s influence within MRO Infra-structural characteristics of operation.

The analysis of the response showed that the Lean has been most influential in the ‘*Human Resources*’, ‘*Quality Control*’ and ‘*Performance Measurement*’ strategic business decision areas. While ‘*Human Resources*’ characteristic of operation deals with the workers skills, defined routines, training programmes and working culture within the organisation, the *Performance Measurement* characteristic of operation covers the methods and metrics by which the organisations assess their performance. *Quality Control* refers to quality conformance, product assurance and customer satisfaction. The higher rating of Lean’s influence in these three areas suggests that there is more emphasis on measuring (employee) performance in meeting quality expectations. At the core of Lean implementation is the

workforce and the successful integration of the workers into the operation systems is crucial. In practice, literature suggests that this would involve: the division of labour; defined and controlled production systems; increased emphasis on worker skills, attitudes, motivation; improved quality of the product and service (Karlsson and Ahlstrom (1996)). Thus, the relatively higher rating of Lean in the *Human Resources* characteristics of operation is a positive outcome.

Whilst organisations already have performance measuring methods and metrics, the relatively higher rating of Lean's influence in the *Performance Measurement* characteristic of operation is not unusual. However, if the metrics chosen are not correct the outcome may be counter-productive. Literature reveals that traditional metrics have not worked and the major inadequacies with these metrics range from traditional metrics not being able provide enough information as to the root problems (Malone and Sinnott, 2005); or that they largely ignore value creation (Bicheno, 2004; Womack and Jones, 2005). Whilst this empirical study did not explore what metrics have been chosen, the observation so far indicate that the emphasis with the performance measurement will be centred on internal production activities. Bhasin (2008) suggest that companies need to embrace measures that facilitate balancing external pressures, (customer satisfaction), in conjunction with internal pressures (employee satisfaction). In isolation, an internal measure may intimate that a company is performing well whilst the external measures depict poor performance; shrinking the defect rates may be in line with internal strategy, yet the company could be viewed negatively by the market resulting in a deterioration of its share price.

Furthermore, apart from production cost savings, another major motivation for the application of Lean in the aviation MRO industry is turn-around-time reduction (Andrew et al., 2008). Although these motivations could improve the competitive advantage of the company, they are incomplete in describing the MRO motivations especially as these motivations are largely limited to shopfloor production. Thus, it can be said that the metrics that would be more popular in the aviation MRO industry would be more production orientated, such as labour utilisation, production cost and TAT. However, customisable metrics that account for the relational aspects of production will be few in number. If indeed the long-term success of Lean is dependent on the attitude and motivations of the people in the production system (Baines et al., 2004), the lack of appropriate metrics that account for the relational aspects suggest that the emphasis of Lean implementation has been focused on

the tools and techniques which can be readily applied to product and not the Lean philosophy itself. The Lean philosophy, advocates a paradigm change in the way the whole operation system is run; both the transactional and the relational aspects (Womack et al., 1990). Invariably, if the focus of Lean is not correctly appropriated (Finding 8), there is a possibility of the performance metrics being insufficient.

Further substantiating the MRO Lean engagement predominant focus on production (manufacturing-type) activities the relatively lower rating of Lean's influence in '*New Product/Service Introduction*', '*Customer Relations*' and '*Supplier Relations*'. The relatively low product range of the aviation industry and its specialist nature may be the reason for Lean's relatively low performance with regard to *New Product/Service introduction* (Haque, 2003). However, the low ratings in '*Customer Relations*' and '*Supplier Relations*' is consistent with further supports previous observations that the Lean implementation has been focused more on the physical aspects of MRO operations than the non-physical (relational) aspects. Mathaisel (2005) suggests that the reason for this is because it is easier to see waste on the shopfloor than anywhere else. However, the increased intensity in global competition highlights service, flexibility, customisation and innovation as the key competitive parameters (Womack and Jones, 2005) and if the MRO Lean engagements is weaker in the '*Customer Relations*' and '*Supplier Relations*' areas, then competition is hampered. This has led the authors to conclude that:

#### Finding 6

Clarity is still need in directing the MRO Lean engagements within the infrastructural characteristics of operation to facilitate enhanced competitive positioning.

Similar to the outcome in the structural characteristics of operation, secondary observation was noticed with regards to the influence of Lean within the infrastructural characteristics of operation. It was observed from the analyses that the *Performance Measurement* characteristic of operation is linked with *Human Resources* characteristics of operation and that the relationship between these two areas is also linked with the *Quality* characteristic of operation. Invariable, the influence of Lean in the *Performance Measurement* area should produce a commiserate effect in the *Human Resources area* and likewise the *Quality*

characteristic of operation. Whilst the links is not expressly clear with the other infrastructural characteristics of operation, the identified links can be mathematically expressed as:

$$\textit{Lean influence (ISC): } PM \propto Q \propto HR$$

Where;

ISC = Infra-structural Characteristics of Operation

PM =Performance measurement

Q = Quality

HR = Human Resources

The final question of the survey sought to understand how the respondents perceived each characteristics of operation since Lean introduction. The analysed responses are as presented in Figure 4.15.

Whilst only a few options were provided to the respondents, it was observed from the results that most organisations indicated an average status in terms of how proud they were of the different areas. This indicates that although they had implemented Lean, the perception towards its performance as it applies to their operations were still average. Although the reasons as to this outcome was not further explored in the survey, a mismatch in the expectations of Lean and what is being recorded to lead to this average rating. Bhasin (2008) suggest that less than 10 per cent of UK organisations accomplish successful Lean implementations and as such, whilst the survey records that there have been some successes to Lean implementation (Finding 4), the culmination of the findings from this survey and as observed from literature especially the adaptation of Lean to suit the MRO environment could serve as reason for this outcome.

## Profiling the performance status of MRO characteristics of operation

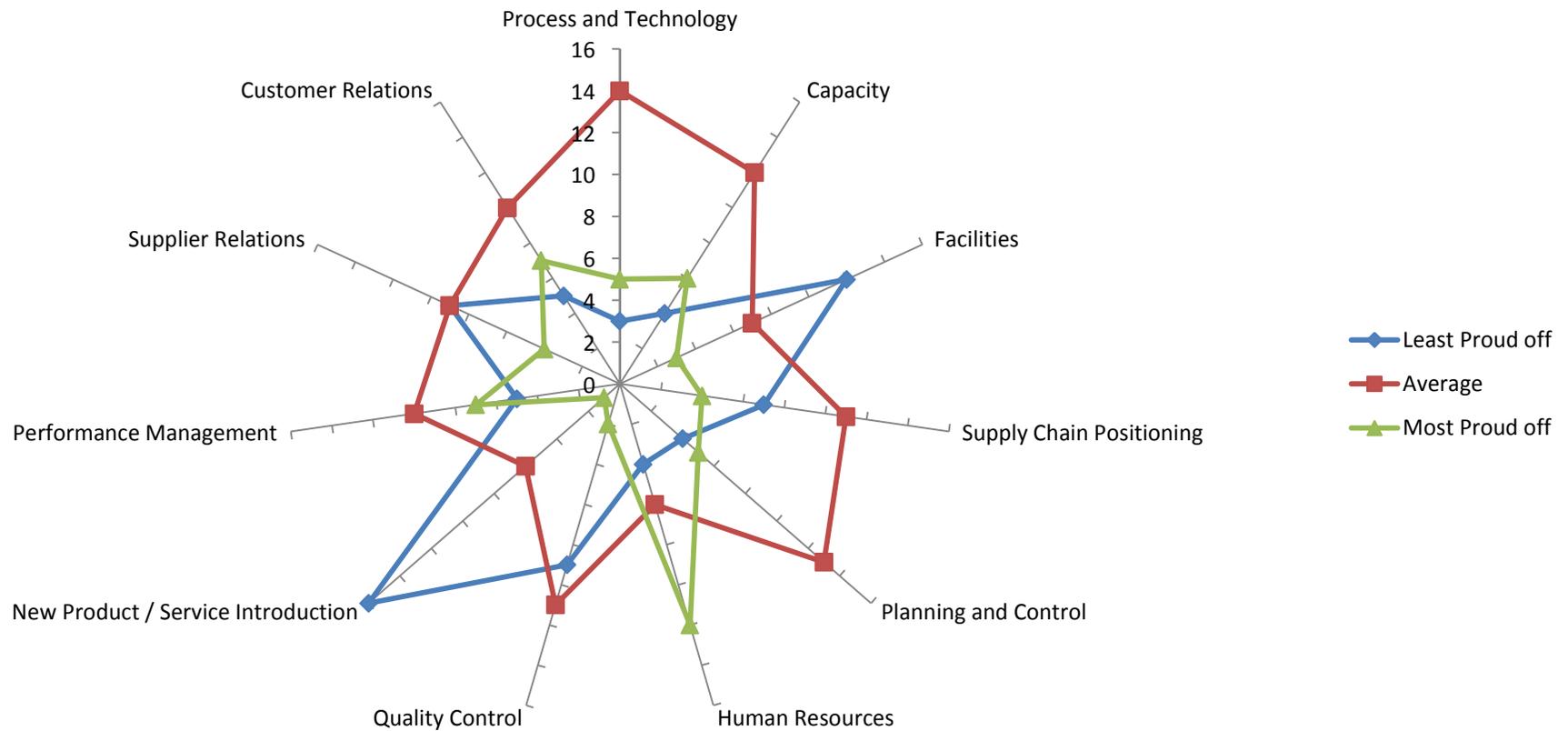


Figure 4.17: Profiling the performance status of each characteristic of operation

#### 4.8 Discussion.

MRO framework is made up of both production-orientated and service-orientated functions (Al-Kaabi et al., 2007). These functions can be described in conventional manufacturing and service terms. Although neither description of the industry is incorrect, they are independently incomplete descriptions of the MRO industry. This is because the MRO industry has elements akin to the traditional manufacturing environments and traditional service environments. As such, literature review refers to the MRO industry as a product-centric service industry. Thus, the extent of Lean adoption within the MRO industry has to be established within the scope of these two aspects.

Often the primary goal of Lean implementation has been to increase outcomes like productivity, reduce lead times and costs, improve quality in a manufacturing shop, factory or company (Sriparavastu, 1997). Analyses of the responses reveal that significant improvements were recorded in all outputs of production. Most notable of them was in Labour Productivity, Quality and Production Cost. Although the actual percentage improvements were not recorded, this finding further validates the success attributed to Lean by many organisations. However, the uniqueness of the MRO environment requires that Lean implementation is not limited to purely production activities but to also include service-orientated activities and also, not only the internal aspects (production outcomes) but also the external aspects (market and competition).

The survey also set out to find out the extent of Lean adoption within the aviation MRO industry by considering its influence within identified key characteristics of operation also referred to as the key business decision areas. This interest is based on the proposition that successful implementation of Lean will be translated and filtered across all these key areas, both structural and infrastructural. Analysis of the responses within the key structural characteristics of operation showed that the strategic decision areas that have been most influenced by Lean are *'Process & Technology'* and *'Planning and Control'*. This suggests that Lean tools are being employed in enhancing both the production process that the planning systems responsible for production. Conversely, the responses indicate Lean to have the lesser impacts in the *'Facility'* and *'Supply Chain'* structural characteristics of operation.

With the '*Facility*' decision area representing the proximity of the organisation to customers, suppliers and markets and the '*Supply Chain*' area representing the position of the organisation within the MRO production footprint; it can be observed that the MRO industry had not sufficiently employed Lean approaches in dealing with agile and quick customer requirements.

Similarly, analysis of the results indicate that more emphasis on Lean have been placed within the '*Human Resources*', '*Quality Control*' and '*Performance Measurement*' infrastructural characteristics of operation. Lean is associated with the effective integration of people into their production systems through the division of labour and defined and controlled production systems (Womack and Jones, 1996). The responses from this section suggest that emphasis has been placed on worker skills, their attitudes and motivation whilst ensuring that product quality is maintained. The results indicate that emphasis have been placed on the measuring metrics employed in evaluating the performance of various organisations. Although this survey did not explore what exact measuring metrics have been employed and their appropriateness, it is expected that the adopted metrics would be relatively limited to measuring production outputs such as labour utilisation, production cost and TAT savings with relatively lower focus on their service orientated functions where appropriate customisable metrics would have to be developed.

Conversely, it was noted from the response that Lean was least rated in areas such as '*New Product/Service Introduction*', '*Customer Relations*' and '*Supplier Relations*'. The relatively low product range of the aviation industry and its specialist nature may be the reason for Lean's relatively poor performance in the *New Product/Service Introduction*. However, the lower ratings in the relational aspects such as '*Customer Relations*' and '*Supplier Relations*' supports the overwhelming finding that the focus of Lean has mainly directed toward production-orientated functions where Mathaisel (2005) suggests, is more easy to see waste. The application of Lean to the service-orientated functions is notably lacking.

Furthermore, analysis reveals all the respondent organisations were more active within their production functions than they were within their service operations. Although Pettersen (2009) suggest that Lean programmes are plant specific, it was observable from the responses that the larger the organisation, the more receptive they were to the adoption of Lean as evidenced by the number of tools adopted. However, majority of the tools that were adopted

are more closely linked to their production-orientated activities than the service-orientated activities. This finding could either be a result of a deliberate phased implementation of Lean to first address the production related concerns and then the service related concerns or it could be the a result of the lack of a coherent and holistic approach of Lean implementation within a product-centric service environment. Notwithstanding, casual linkages between the size of the production footprint and the motivation for the adoption of Lean could still be drawn.

The overwhelming conclusion of this survey is that although Lean has been implemented in the aviation MRO industry, its implementation has been limited to the production shop-floor activities where waste is more easily noticed with little attention paid to the service-related operation of the industry. Although Zayco (1997) and Ahlström (1998) advocate for the gradual implementation of the elements of Lean, the overall success of MRO Lean programmes can only be accurately measured when an integrated approach addressing both the production and service aspects of the business is adopted.

This research provides evidence to the adoption of Lean in the aviation MRO industry albeit limited to the production-orientated operations with less attention provided to the service orientated operations. However, without wanting to undermine the value of this study, it should be noted that the findings from this survey should be treated as indicative. Based on the outcome of this empirical study, the author recommend further research into an integrated approach of Lean implementation that concurrently considers its adoption not only to address production issues but a holistic approach that facilitates competitive advantage.

#### 4.9 Review and summary of the motivation of the empirical study.

The empirical study described in this chapter sought to engage the MRO industry in trying to validate literature review findings and to also get a better understanding of MRO Lean engagements. Informed by literature, the motivation for this study was distilled into the following empirical research questions:

- **Survey Question 1:** What is the footprint of your operation?
- **Survey Question 2:** What is nature of Lean engagement?

- **Survey Question 3:** What is Lean’s influence within the context your operational framework?
- **Survey Question 4:** What are the results since the introduction of Lean?

This led to a number of key findings which are summarised in Table 4.3.

#	Findings
1	Prevalent MRO operation footprint is more inclined towards its in-house production activities and as such, there is a high tendency for Lean to be viewed and interpreted purely as a waste reduction tool.
2	MRO Lean engagements have resulted in the application of several Lean tools and practices; however, clarity is still needed in how to adapt Lean to the MRO context.
3	The nature of MRO Lean engagements is not holistic in its realisation to facilitate competitive advantage.
4	The outcome of MRO Lean engagement albeit positive still requires clarification as to how to appropriate its application to facilitate competitive advantage.
5	The proliferation of Lean within the transactional aspects of MRO operations is positive; although this outcome has more Lean tools and practices based than Lean thinking based.
6	Clarity is still need in directing the MRO Lean engagements within the infrastructural characteristics of operation to facilitate enhanced competitive positioning.

**Table 4.3: Summary of the Findings from the empirical study**

The first objective of this research was to establish the state-of-the-art of Lean within MRO context. This was achieved via literature review (Chapter 2) and an empirical study (Chapter 4). The empirical study was necessitated due to the weakness in literature. However, a few key similarities could be drawn both studies which is as presented in Figure 4.18. The combination of the empirical study and the literature review complement each other to provide a more comprehensive understanding of the state-of-the-art of Lean in aviation MRO context.

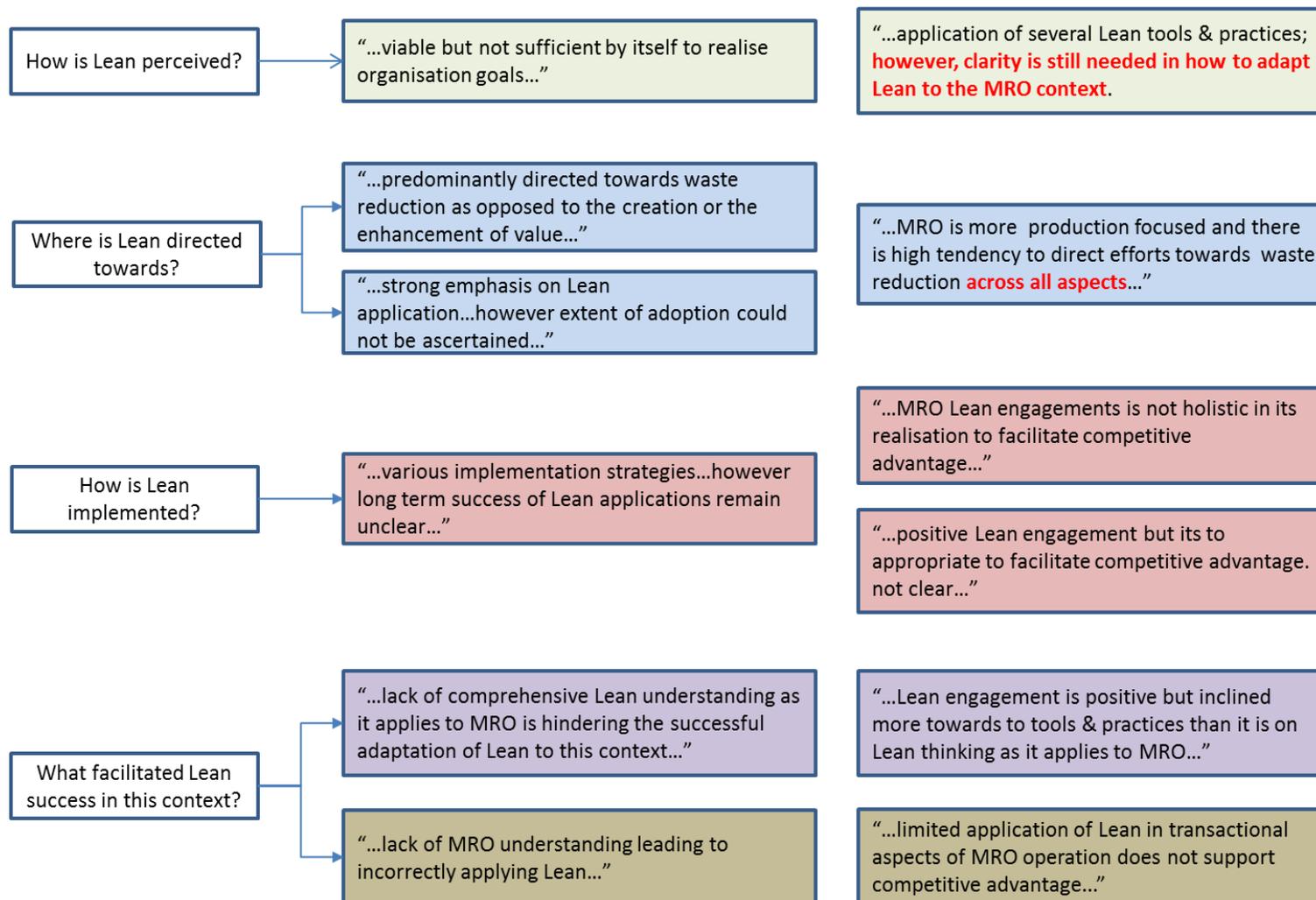


Figure 4.18: Establishing the status of MRO Lean Engagements (comparing Literature and Empirical perspectives)

With regard to the perception of Lean; while literature review alluded to the positive adoption of Lean in MRO context, it was observed from the empirical study that the nature of Lean engagement resulted in adoption Lean tools & practices along with other practices like Agile and Six-Sigma. While authors like Andersson et al., (2006) will present the case to the distinct nature of these practices, other others like Dahlgaard et al., (2006) will argue that they are both subsets of each other. Whatever the case, the application of all these practices within MRO suggests a lack of clarity as to how Lean is to be applied within this context.

Similarly, it was observed from literature that there were various implementation strategies for Lean in MRO. Whilst the strategy of the Lean engagement was not directly explored, it was observed from the empirical study that emphasis within MRO was more inclined towards the physical (transactional) aspects of production and as such, the focus of Lean's application was directed towards these areas when waste is more easily seen. With literature indicating that Lean is plant specific, the various implementation strategies for Lean adoption would relate more with the application of Lean tools and techniques. However, the strategy with the adoption of Lean as it pertains to the overall business intent with regards to competitiveness still requires clarity.

Finally, it was observed from literature that a lack of understanding of Lean and the context of application could serve as hindrances to the Lean's advancement or success. Whilst positive outcomes since the application of Lean was recorded from the empirical study, the skewed emphasis on the aspects of its production (evidenced by the rating of Lean's influence in the characteristics of operation), suggest that there is still a lack of understanding of how to adapt Lean to suit the MRO context.

Although there is an overall positive affinity for Lean within MRO, the outcome of both studies (literature review and empirical study) leads the author to make the following conclusions about the state-of-the-art of Lean in MRO.

- The production focus of MRO organisation narrows the application of Lean to waste removal (mainly shopfloor application) and as such, Lean is viewed as a viable but not sufficient enough in achieving business goals (or enhance competitive advantage).

- Although there is a positive affinity for Lean in MRO, there is a lack of know-how in how to adapt Lean to MRO context.
- The prevalent approach to Lean engagement within the MRO industry has not been holistic with focus of Lean application mainly directed towards the operational context.
- Clarity is still needed with how Lean can be applied within the aviation MRO context to facilitate competitive advantage.

Based on these findings, the following sections of this thesis will first present the MRO context in more detail (Chapter 5) and then, the role of Lean within MRO with the particular motivation of enhancing competitive advantage (Chapter 6) with a case exemplar.

## 5. ESTABLISHING HOW THE MRO REALISES ITS VALUE PROPOSITION

This research is premised on the ubiquitous application of Lean within the MRO industry to mitigate industry challenges with the hope of realising the similar outcomes to those seen in the automotive industry. To this end, the status of MRO Lean engagements was established via a literature review (presented in Chapter 2) and an empirical study (presented in Chapter 4). It was observed that although the application of Lean within MRO resulted in operational benefits, there was still a lack in know-how in how to adapt Lean to MRO context. Also, it was observed that prevalent approach to Lean engagement within the MRO industry was not *holistic* with focus of Lean application mainly directed towards the operational (shopfloor). Whilst the application to the shopfloor is certainly important, it is remained unclear whether this limited focus of Lean application translates into competitive advantage. As such this chapter seek to establish the complete means through which MRO realises it value proposition.

Thus, first captured in this chapter is an introduction Section 5.1, then the development of the MRO value delivery system (Section 5.2 through to Section 5.7). The critical resources associated with the MRO value delivery system is presented in section 5.8 and an overview of the chapter is presented in section 5.9.

## 5.1 Introduction

As established from the literature review (Chapter 2), the main ideal of Lean thinking is to eliminate waste and enhance value. Common definition of 'value' is usually described in terms of the difference between perceived benefits and perceived costs. The higher this margin, the more value is seemed to be derived. Value is created when a product or service meet specific customer needs (Kambil et al., 1996). This is consistent with Chesbrough and Rosenbloom (2002) assertion that value is an outcome of the solution proffered to a customer's problem as assessed from customer's perspective. This suggests that the perception of the customer ultimately determines value. Thus, the proposition offered by the company to meet the customer's needs should be consistent in delivering what the customer considers to be of value. The value proposition of an organisation should capture how the organisation's offer differs from those of its competitors and explains why the customer should prefer their solution over another (Lindic et al., 2011). The value proposition should provide focused and distinct benefits that help to address the customers' problems by being **distinctive** (i.e. superior to those of its competitors), **measurable** (i.e. based on tangible points of difference) and **sustainable** (i.e. valid for a certain time period) (Anderson et al., 2006; lindic et al. 2011). Therefore, although the value proposition is about the customer needs, its purpose is internal and it describes the solution the organisation intends to provide to the customer. The following sections of this chapters clarifies the means through which MRO realise their value proposition (i.e. deliver value) with the view of enhancing their competitive positioning.

## 5.2 Developing the MRO Value Delivery System (VDS)

It is paramount that in the successful realisation of Lean in the aviation MRO industry is not only in context of waste elimination but also the creation and enhancement of value as determined by the customer. Interestingly, Anderson et al. (2006, p. 2) suggests that it is difficult to find examples of value proposition that resonate with customers. Lindic et al., (2011) suggest that companies usually think of value proposition in terms of what they offer their customers rather than what the customers truly value (Bower and Christensen, 1995; Christensen and Overdorf, 2000). Conversely, it was observed from status of MRO Lean engagement that the *focus* of Lean is predominantly to deal with waste elimination. However,

if the intent of Lean application is to enhance competitive advantage, its *focus* should not only address waste elimination but equally important, the *focus* of Lean application should address enhancing value.

Many MRO organisations have various structures that are responsible for the delivering of value. However, the core of these structures is largely similar. An organisation may have different departments and processes and though each has a different function, they all operate under one core objective. This core objective is what feeds into the different department and drives how they operate and consequentially, how value is delivered. This core objective is described as the business model of that organisation. Although this research will not examine all the different departments that exist with the typical MRO organisation; this research will provide clarity to the system that describes how MRO value proposition is realised. This system is described as the MRO Value Delivery System (VDS).

The Value Delivery System (VDS) is the interdependent network through which an organisation is able to fulfil and realise the value the offer - value proposition (Yung & Chan, 2003). The aspects of the VDS critical to realising its value proposition are People, Processes and Procedures, Facilities and Equipment (Swartz, 1994). Whilst the VDS is not the same as the strategy of the company, the VDS is the means through which the business strategy is optimally realised. Yung & Chan, (2003) suggest that the organisations that are highly competitive are to design their VDS by transforming their process intents and process models to enhance the flexibility of the organisation to adapt to the constantly changing market and customer demand. With flexibility increasingly becoming a key performance indicator with especially with regards to competitiveness, the more competitive organisations excel because of their ability to develop a delivery system superior in competitive priorities such as Quality, Value-to-cost ratio and Responsiveness.

There are four characteristics to the value delivery system (VDS). These characteristics include: Intent; Model; Control and Evaluation; and Learning system. The relationship between these characteristics is as shown in Figure 5.1. Whilst the expression of these characteristics may vary from one organisation to another, the suitability its development is determined by how well it realises the value proposition by minimizing the non-value adding activities and by constantly improving business deliverables (Yung & Chan, 2003).

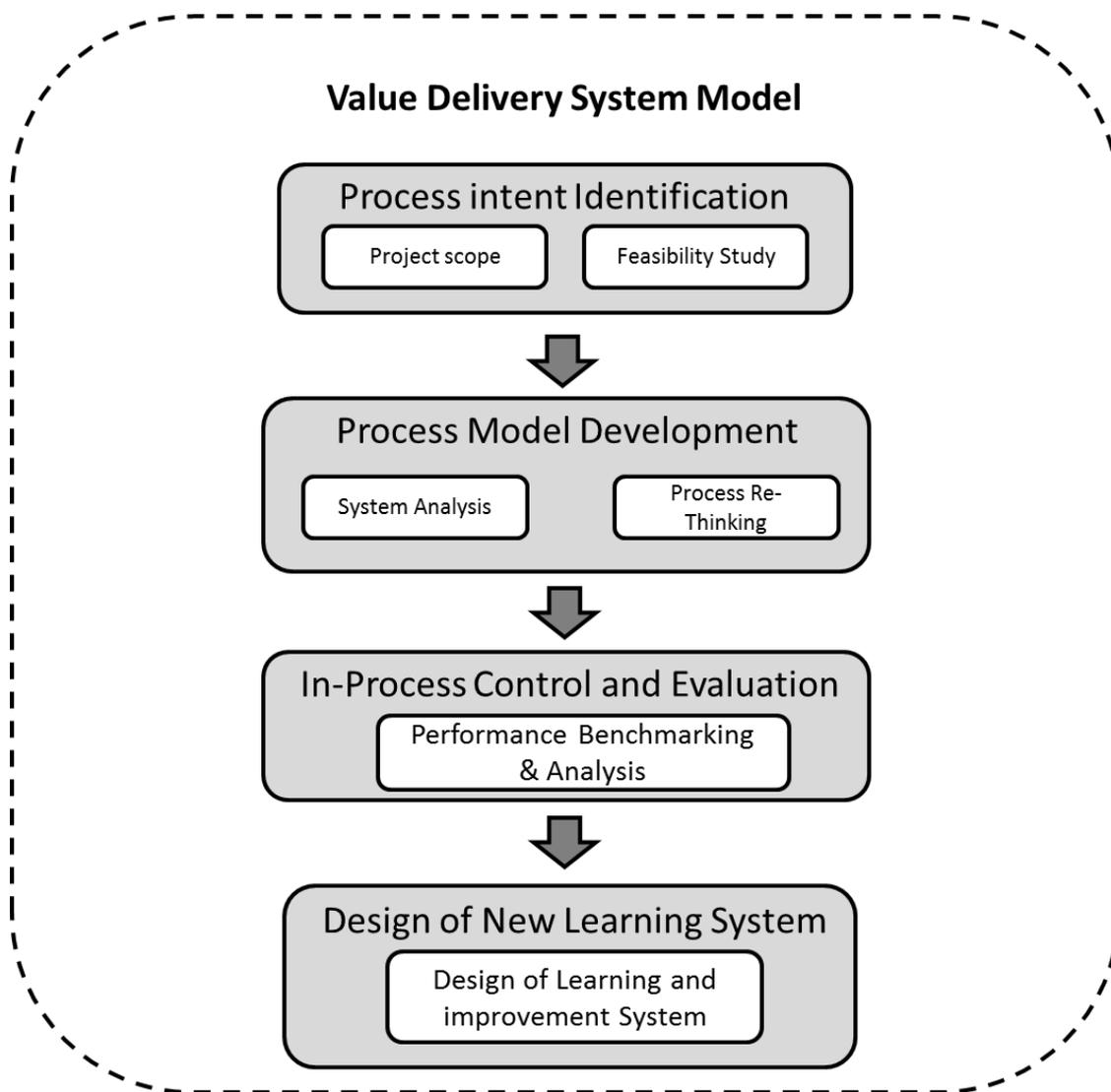


Figure 5.1: Characteristics of the Value Delivery System model (Yung & Chan, 2003) [Adapted].

Although the four characteristics to the VDS remain a common feature to the development of the VDS, they are versatile and can be adapted to suit various purposes. These purposes can range from forming the framework to how an organisation realises its value proposition to helping to inform a unique project achieve its goals. Based on the development of the VDS with regards to Flexible Business Process Reengineering (FBPR) by Yung & Chan, (2003), this research extends this to the aviation MRO context. The following explanations are the author's proposal as to what each of these characteristic entails with regard to the development of the MRO value delivery system (VDS).

1. **Intent:** This refers to the organisation determining the direction of the business. This can be achieved through benchmarking with other competitors. The outcome of this analysis provides an accurate understanding of the relative positioning of the organisation within competitive environment. This can involve Competitive Position Mapping. The competitive position mapping refers to identifying the relative position of the organisation within the context of its competitive environment. Porter's five forces of competition as presented in chapter 6 provide a good basis for understanding where an organisation lies relative to its competitors. The outcome of this analysis will not only provide a relative status of the organisation but it should also reveal the performance differences (gaps) which will be crucial in informing the development of the intent. Based on the outcome of this analysis, the competitive intent of the organisation is then determined with supporting plans which will serve as the blueprint that organises the resources and directs future activities of the organisation.
  
2. **Model development:** Based on the determination of the Intent, the framework through which this intent is to be realised is then developed. This model involves assessing the current state of the business and redesigning the (elements of the) model to be consistent with the intent. Yung & Chan, (2003) suggest that the model development will involve:
  - a) **System analysis.** This refers to the complete familiarisation with the current working system through audits and benchmarking using competitive performance indicators – Cost, Quality, Delivery, flexibility and Innovation. It is important that the analysis takes into consideration all aspects of the competitive performance indicators to get an accurate understanding of the business so that any current problems that are inherent in the system are fully understood. Also, making improvement changes to only one business activity and isolating others may be sub-optimal, since improvement to one area may consequently affect subsequent business operating areas it is vitally important to take into consideration during the analysis, all aspects of the competitive indicators.
  
  - b) **Model re-thinking:** Along with the system analysis, the assumptions upon which the current model is built on should also be re-evaluated especially to check for consistency and relevance to current external factors (including the competitive climate). This process can reveal latent problems which may not have been identified

through the system analysis. Potential solutions can then be identified new system rules and processes can be generated on this outcome of these steps.

3. **Control and Evaluation:** The value delivery system is not limited to *how* the value proposition is being realised but also (the quality of) *what* is being realised. The target of all organisations would include a “built-in quality” system within all their imminent products and services (Yung & Chan, 2003), and as such, also included in the VDS should be quality monitoring and benchmarking. A Lean tool that can be used to this end is a Failure Mode Effect Analysis (FMEA) which is a good way of identifying deviations from the ideal in an order of priority which should then inform the counter-measure initiatives that address these deviations
  
4. **Learning System:** The final characteristic to the VDS constantly drives the organisation towards improving its competitiveness. This VDS is not limited to carrying out periodic static assessment of the organisation and making necessary adjustment, but to also include a dynamic means through which all aspects of the system (People, Processes and Procedures, Facilities and Equipment etc) are moving closer and aligned to the intent. This will involve not only engaging and challenging the mind-set of the people but also re-evaluating the intent of the business. It will also involve employing relevant management methodologies and updated technologies to exploit the model and improve the competitive positioning of the organisation.

All of these four characteristics provide the conceptual framework for the value delivery system that drives towards improved competitiveness (Yung & Chan, 2003). Whilst there is not a universal model that fits all, the VDS is represented and operationalised within the business model of an organisation.

### 5.3 Delineating the MRO Value Delivery System from the Business Model Framework

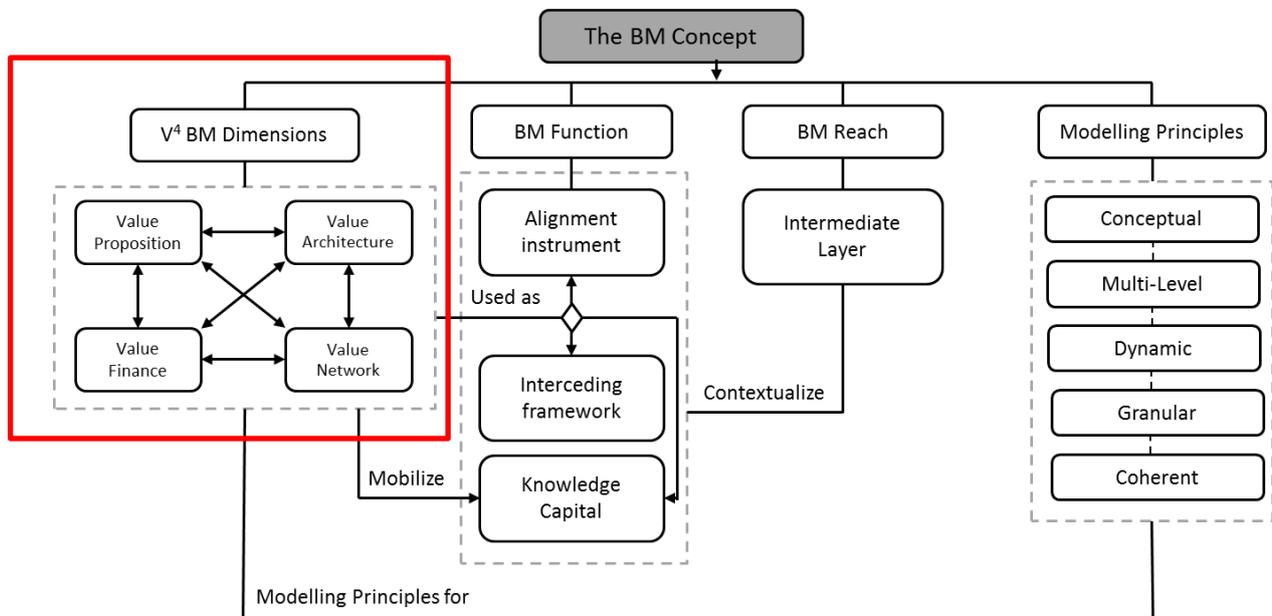
The term business model is used in different context both formal and informal to describe the core objective of a business. The business model is fundamental to any organization (Magretta, 2002). The business model captures the certain core aspects of the business which includes the business purpose, business process, target customers, offerings, strategies,

infrastructure, organizational structures, trading practices, and operational processes and policies (Pateli & Giaglis, 2004; Osterwalder et al., 2005; Shafer et al., 2005). Morris, (2003) described a business model as “a concise representation of how an interrelated set of decision variables in the areas of strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets”. Albers (2013) suggests that the model captures the essence of how the business system will be focused and outlines the architecture of revenues, costs, and profits associated with the business enterprise delivering that value. Thus, the business model can be described as the ‘how’ an organisation business converts its products and services into value in the most efficient and effective manner possible. As such, the elements of the value delivery system should also be encapsulated in the business model.

Given the nature of what a business model represents, there have been diversities in what a good business model should constitute. These diversities have sometimes led to confusion in the terminologies with terms such as business strategy, business concept, and business plans being used interchangeably. In other cases, the business model has been referred to as architecture, design, pattern, plan, method, assumption, and statement. Although these terms are closely linked; they are distinct in themselves. Although the business model captures key components of a business plan, the plan deals with a number of operational issues that may transcend the model. The business model is not equivalent to the business strategy even though it does contain elements of the strategy. Similarly, the business model is not an activity set, although activity sets support each element of a model. Although the relative closeness of these managerial terms has led to diversities in describing what a business model is, the business model has been referred to as architecture, design, pattern, plan, method, assumption, and statement.

Many authors have tried to bring order to the different descriptions of what a business model actually constitute. For example, Morris et al, (2005) was able to bring order to the various descriptions of the business model and categorise them based on the principal emphasis each perspective lay. Likewise, Zott and Amit (2009) were also able to bring some order to these various descriptions by considering the dominant value creation drivers in greater detail. However, carried out a comprehensive review of the literature, to develop a unified framework of the business model concept. This framework comprised of four fundamental aspects. The first aspect delineated the primary business model dimensions along with their constituent elements. The second aspect cohesively organised the guidelines and features of

the business model. The third aspect focused on the interactions and intersections between strategy and processes whilst the fourth aspect the main functions of the business model especially with regards to its practical significance of the concept. Figure Figure 5.2 and provides an overview of the unified business model framework.



**Figure 5.2: Unified business model framework (Al-Debei & Avison, 2010).**

Al-Debei & Avison (2010) described and represented the first fundamental aspect to the business model as V<sup>4</sup>BM Dimensions which represents the four value dimensions of the business model. These four value dimensions are the *Value Proposition*, *Value Architecture*, *Value Network* and *Value Finance*. It is within value dimension that the Value Delivery System is evident. Al-Debei & Avison (2010) describe the value dimensions as:

- **Value Proposition:** This dimension refers to the business model as a description of the ‘products’ (inclusive of services) an organisation offers, or will offer. The value proposition also describes the elements and governing protocols incorporated within the offering, as well as the nature of targeted market segment(s) along with their preferences. This value dimension is usually captured in the strategic intent of the organisation.
- **Value Architecture:** This value dimension covers the description of the organisation infrastructure and its configurations. This value dimensions comprises of the tangible

and intangible assets, resources, and core competencies. This dimension lays more emphasis on the resources and how value can be generated to sustain competitive advantage. This value dimension focuses on the economical use of the resources of the organisation.

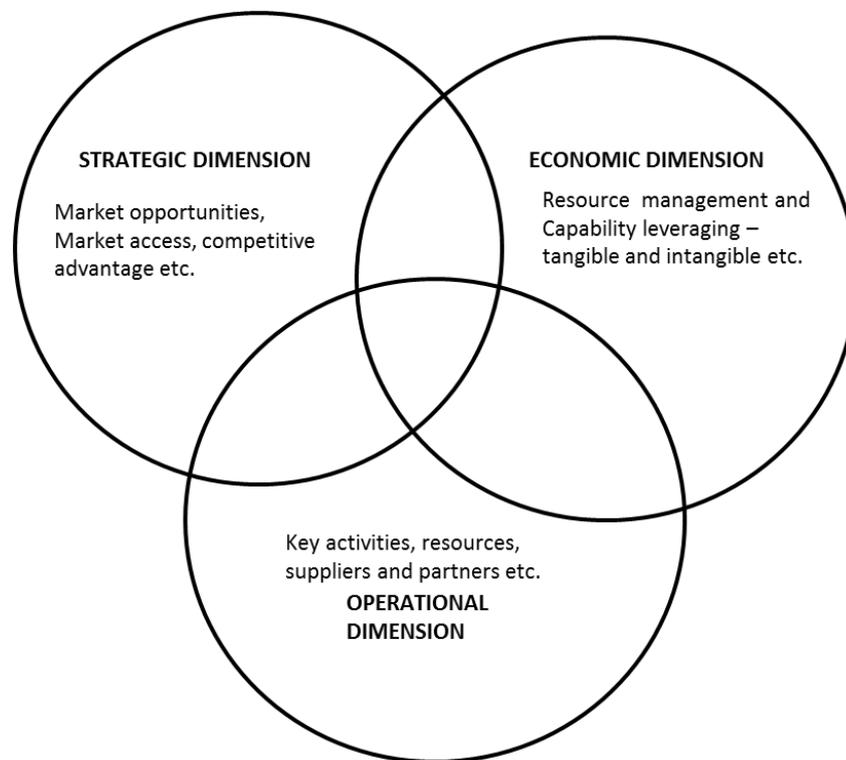
- **Value Network:** This value dimension refers to the way in which the flow of value is enabled through the coordination and collaboration via channels and among stakeholders. This value dimension describes the flow of value both within the organisation and cross-company. This dimension is representative of the operations of the organisation in transacting value to the customer.
- **Value Finance:** This dimension represents the way in which organisation generates revenue. Similar to the value architecture dimension, this value dimension is also focus on the financial and economic designs within the organisations. It covers the areas relating to costing, pricing methods, and revenue structure and as such, the role this dimension plays is mutually vital to all the other three dimensions.

All of these dimensions are substantially interrelated and interdependent. The VDS of any organisation is represented within the relationships that exist between these dimensions. The balance of the relationships between these value dimensions represents how an organisation is able to transact value to the customer sustaining their competitive positioning. The realisation of Lean within the understanding of the VDS ensures that the focus of Lean application is correctly appropriated in a way that is facilitates competitive advantage.

The V<sup>4</sup>BM aspect of the business model concept proposed by Al-Debei & Avison (2010) captures the system through which value is delivered – Value delivery system. Consistent with the characteristics of a VDS described earlier, the V<sup>4</sup>BM comprises of the intent (value proposition), the framework (value architecture), the control and evaluation (value finance) and the learning system (value network).

Based on the assessment of the V<sup>4</sup>BM concept and its consistency with the characteristics of what a VDS entails, this research operationalises the value dimensions within the aviation MRO context as having a *Strategic dimension* (Value Proposition and Value Network), an

*Economic dimension* (Value Finance) and an *Operational dimension* (Value Architecture). The *strategic, economic* and *operational* terms whilst still consistent with Al-Debei & Avison (2010) taxonomy employ industrial language to show alignment as shown in Figure 5.3.



**Figure 5.3: Bringing order to the different description of the MRO business Model**

At the most rudimentary level, the VDS is comprised of the firm's economic model (Morris, 2005). However, the *Economic Dimension* is not exhaustive in describing the firm's VDS as some have alluded to (Timmers, 1998; Linder & Cantrell (2000)). These descriptions most times regard only the protocols that govern the revenue and profit generating systems of the organisation. Some of the *Key Business Decision Areas* (KBDA) within the economic dimension includes decision variables such as revenue sources, pricing methodologies, cost structures and margins. Although the economic framework of the organisation is a key aspect of the VDS, it is not sufficient by itself in describing the 'how' value is delivered but only describes the profit generation framework of the organisation.

Conversely, the *Strategic* element of a business model is not exhaustive in describing the VDS by itself albeit being an integral part of it. Slywotzky (1996) alludes that VDS is the

totality of how a company selects its customers, defines and differentiates its offerings, defines the tasks it will perform itself and those it will outsource, configures its resources, goes to market, creates utility for customers and captures profits. The emphasis with this description lies mainly within the competitive advantage and sustainability of the organisation. Some of the governing protocols within this strategic element include the organisation's market positioning, production footprint and competences and growth opportunities. Some of the key business decision areas include stakeholder identification, value creation, differentiation, vision, values, networks and alliances (Morris, 2005).

Within the *Operational Dimension*, VDS is often times referred to as the architectural configuration of the organisation. The focus within this dimension is internal processes and design of infrastructure that enables the firm to create value. Mayo and Brown (1999) describe the VDS as the design of key interdependent systems that create and sustain a competitive business. The adoption of Lean is most times limited to this dimension because it is easier to see the waste in this area without taking into consideration the complete context within which Lean is to be realised. The KBDA within this dimension looks not only at the transformation of the product but also the service that accompanies the delivery of the value by the product. Thus, the KBDA within this dimension includes not only the structural aspects but also the infra-structural aspects such as the workforce necessary to deliver the value.

Irrespective of what terms are used, each of these dimensions is comprised of a unique set of decision variables which together constitute the architecture through which the organisation delivers value. It is within the realm of the variables that Lean is to be successfully realised within the MRO industry. Together, all of the three main dimensions of an organisation's value delivery system represent how the company produces and, or delivers value.

It is uncommon to find organisations to only adopt only one dimension as a sole expression of their value delivery system, what is more common is for organisations to lay more emphasis on a combination of two of the three dimensions to express their value delivery system. These combinations could take the form of either being: *Strategic-Economic*; *Economic-Operational* or *Strategic-Operational*. Whilst none of these perspectives are superior to the other, an organisation may decide to temporarily lay more emphasis on one dimension than the other. However, it is clear that successful realisation of Lean has to be

done within the context of an inter-dependent interaction of the three main dimensions of the value delivery system with the least detrimental effect to the environment.

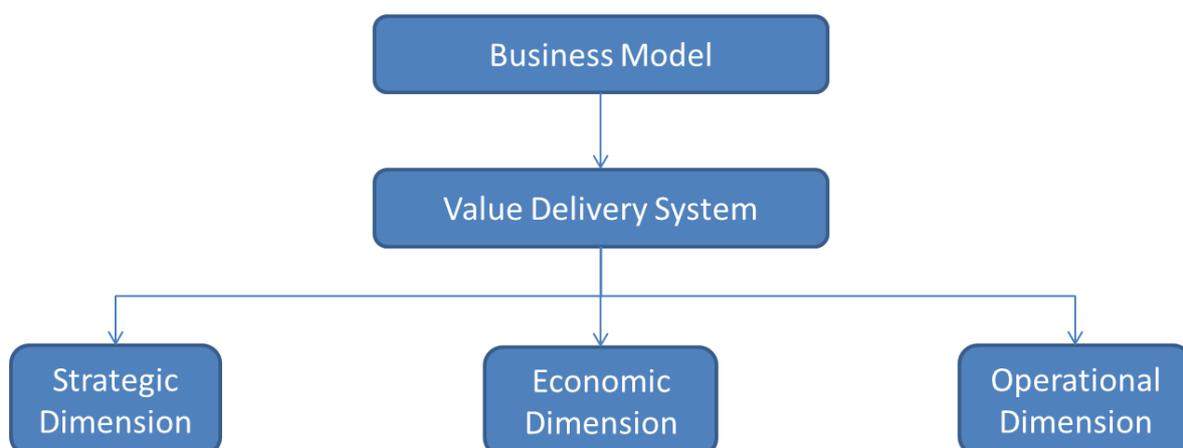
One of the findings from the literature review presented in chapter 2 suggest that one of the factors that may be hindering the successful realisation of Lean within aviation MRO industry may be the lack of clarity and understanding of the business environment in which Lean is to be realised. Thus, a thorough understanding of the aviation MRO business environment should significantly improve the successful realisation of Lean. Indeed the adoption of Lean should take into account all the unique business decision variable of the various dimensions which transcend the architecture of the firm or how it makes money. The adoption of Lean within the MRO industry should be realised within the context of its essence and the system through which it delivers value as opposed to Lean application to a singular dimensions only.

#### 5.4 Dimensions to the MRO Value Delivery/Creation System

Since it has been established that the successful realisation of Lean has to be done within the full context of the value delivery system (VDS), this section seeks to understand the value delivery system of the MRO industry which will facilitate the approach in successfully realising Lean within this context.

In Chapter 2, it was established that the traditional perception of maintenance is usually to 'fix' broken items limits the understanding of maintenance functions to reactive activities alone. This type of maintenance operation is often referred to as reactive maintenance, breakdown maintenance, or corrective maintenance (Albert et al., 1999). More proactive and comprehensive descriptions of the MRO industry include the ones offered by Geraerds (1985) and the Maintenance Engineering Society of Australia (MESA) which assert that MRO industry is responsible for all activities aimed at keeping the product in, or restoring it to, the physical state inclusive of all the engineering decisions and associated actions necessary and sufficient for the optimization of specified capability. When considered in such wider context the MRO could be referred to belong within physical asset management business context.

All of these descriptions of the MRO industry significantly lend towards elucidating the value proposition of the MRO industry offers. Kinnison (2004) suggests that the main value proposition of the MRO industry is to ensure the reliability and safety of the product to meets its design functions. Whilst this is not exhaustive, he goes on to suggest that this value proposition has to be accomplished within required time limits and at a minimal total cost – inclusive of the maintenance cost and the cost of residual failures. Furthermore, he suggests that the *value propositions* are accomplished through the acquisition of necessary product and process information when inherent safety and reliability levels are not met; the tooling design and the component repair information required for the full repair and replacement of parts during the overhaul process. All these extensions thus describe the key business decision areas that influence the value proposition offered by the MRO organisation. Ulrich and Fluri, (1995) suggest that these key business decision areas could be categorised as ‘normative’ (or economic), ‘tactical’ (or strategic) and ‘operative’. These key business decision areas cover each functional and organizational layer of a company and, thus, comprehensively constitute the value delivery system through its cross-sectional and multidimensional character. It is within these key business decision areas that Lean is to be applied for a successful realisation is to be accomplished. It is however important to note that a generic approach will be adopted in understanding the MRO value delivery system. Whilst this approach is sufficient, where crucial, specifics about certain aspects of the industry will be highlighted to bring more understanding to the subject.



**Figure 5.4: Overview of MRO Value Delivery Framework**

## 5.5 MRO Value Delivery System – Strategic Dimension

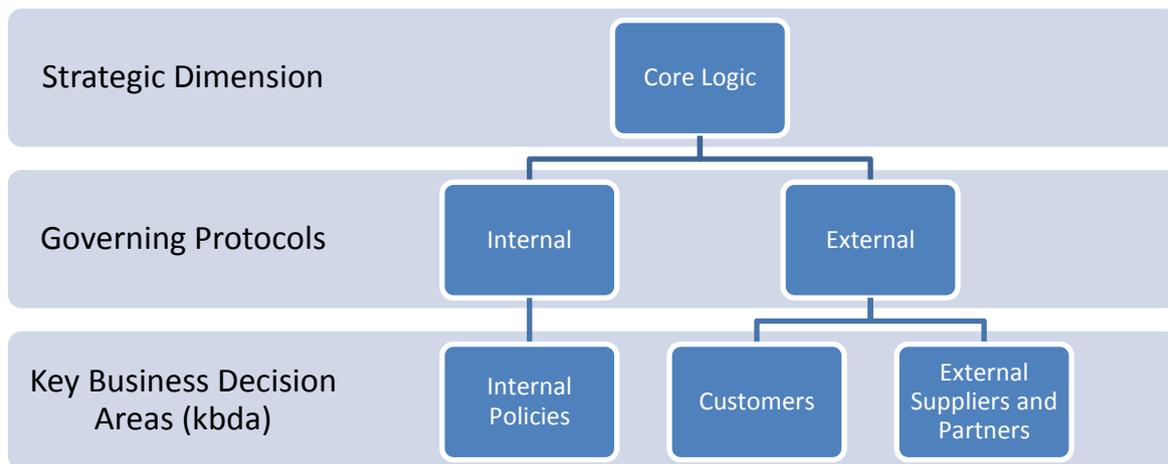
The strategic dimension to the MRO value delivery system focuses on the overall direction in sustaining competitive advantage. This implies the effective and efficient leveraging of resources and capability to achieve superior performance (Grant, 2010). Whilst this research seeks only to explore the strategic dimension to the MRO value delivery system, it is important to note that literature reveals that the strategic dimension exist in three levels:

1. **Corporate Strategy:** *This focuses on the sector of operation, resource acquisition and apportioning throughout the organisation.*
2. **Business Strategy:** *This focuses on the production footprint within the competitive*
3. **Functional Strategy:** *This focuses achieving competitive advantage.*

In line with Mintzberg et al., (1998) and Kvint (2009) assertions, the strategic dimension offers an array of decision areas that are responsible for the long-term success of the organisation. Daft and Albers (2011) were able to summarise all of this different aspects (corporate, business and functional strategy) into the main key decision variable known as the **Core Logic**. The Core Logic demonstrates how the organisation creates and delivers value and it's further explained in following sections of this chapter.

### 5.5.1 Strategic Dimension - Corporate Logic

Daft and Albers (2011) explain that the Core Logic represent the essential values and notions that form the basis for the long-term orientation of the organisation and the essence of how it intends to place itself within the industry (Hamel, 2000). The core logic is also often referred to as the specification of an organisations orientation and its relationship to the environment. It specifies how it leverages on both the *internal orientation* and the *external relationships* to create and deliver value (Hamel, 2000; Shafer et al., 2005). Although they are very closely linked, the internal orientation and the external relationship represent two **governing protocols** of the strategic dimension of the MRO value delivery system. It is within these governing protocols that the key business decision areas exist.



**Figure 5.5: Understanding the aspects to the Strategic Dimensions of the MRO value delivery system**

Within the Internal Protocol, governing the internal orientation of the strategic dimension are the Internal Policies. These internal policies represent the key business decision areas within this protocol. The internal policies subsume the key characteristics of a company's basic internal structure that represent its core values (Daft and Albers, 2011). They cover the elements that define the activities that should be done and by whom (Zott and Amit, 2010). Chandler (2001) suggests that the internal policies can be more accurately represented by distinguishing them into the following:

- **Fundamental business policy:** This represents the organisations production footprint and their competencies. This is more accurately reflected by classification of the industry based on type function as presented in Section 2.4.
- **Labour policies:** This aspect focuses on the organisation's structure according to a common understanding of the organizational layout, organizational superstructure inclusive of the hierarchal architecture and labour intensity.

Within the External Protocol, there are two main key business decision areas which collectively represent the external value network. They represent the organisations links to the relevant actors in its environment which are predominantly the 'Customers' and the 'External partners' needed to develop the value delivery system (Shafer et al., 2005). Both customers and external partners are crucial elements strategic dimension (Daft and Albers, 2011).

The External protocol also governs the inter-organisational relationships especially with regards to outsourcing and the internal orientation focuses on its core competencies. The inter-organisational relationships elucidate as to whether the organisation is more autonomous in nature or operates with the help of an extensive network of external partners. Whilst each has its advantages (Al-Kaabi et al., 2007), this area represents a key business variable that the successful adoption of Lean philosophy can influence. Other inter-organisational relationships exist in the form of embedding of the MRO organisation into relevant associations (for example, IATA) which also lends towards the core logic of the strategic dimension (Hillman and Hitt, 1999).

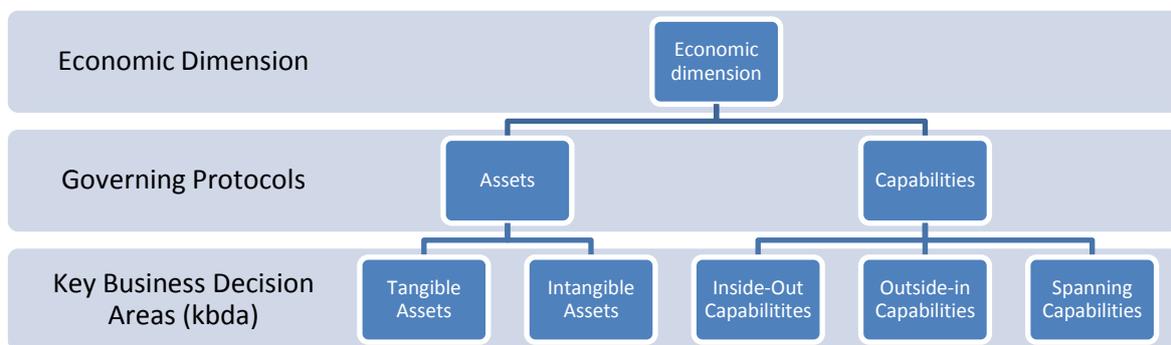
Traditionally, the 'internal operations' refer to the actions which are aimed at improving competitiveness with a focus on the production activities residing within the 'four walls' of the organisation. Many organisations have tended to focus on initiatives such as technology investment, work-in-progress reduction, production scheduling techniques and component make/buy (Baines *et al.*, 2006). Similarly, the 'external operations' refer to the actions that are aimed at improving competitiveness with a focus on production activities that are carried out outside of the 'four walls' of the organisation. Some of the initiatives within this realm reveal the organisations' position on competencies it intends to focus on and those that are being outsourced. It also reveals the strategic positioning, direction and degree of vertical integration and the relationships with suppliers and customers (Hill, 1993).

## 5.6 MRO Value Delivery System – Economic Dimension

A core element of the MRO value delivery system is the Economic Dimension (Linder and Cantrell, 2000). The economic dimension provides a consistent logic for earning profits. The creation and delivery of value provides a justification for the business entity. Morris (2005) explains that the economic dimension can be approached in terms of four subcomponents:

- Operating leverage - focusing on the ratio between the fixed versus variable costs;
- Emphasises volumes as it relates with both the market opportunity and internal capacity;
- Ability to influence the margins;
- Revenue model – focusing on the flexibility of revenue sources and prices.

However, central to these four approaches is the understanding that resources used to conceive and implement the economic dimension are referred to as ‘**Assets**’ and ‘**Capability (ies)**’ (Barney & Arikan, 2001, p. 138)”. Whilst **Assets** could either be *tangible* or *intangible*, **Capability** is referred to as the ability of the organisation to develop and leverage on resources to affect the costs and the revenue-generating potential of the organisations’ productive activities (Grant, 1996b; (Teece, Pisano, & Shuen, 1997). The main governing protocols within the Economic Dimension are Assets and Capability and this section seeks to provide more understanding of these areas particularly as it pertains to the MRO industry.



**Figure 5.6: Understanding the aspects to the Economic Dimension to the MRO Value Delivery System**

### 5.6.1 Economic Dimension - Assets

Anything that is capable of being owned or controlled to produce value and that is held to have positive economic value is considered an **Asset** (Author and Sheffrin, 2003). An asset is a resource controlled by the entity from which economic benefits are expected to flow to the entity\*\*\*\*. Assets are of two types - *tangible* or *intangible* Assets. Whilst *tangible* assets are those that have a physical substance; (such as buildings, inventories, equipment) *intangible* assets are identifiable non-monetary asset without physical substance (such as Computer programmes, trademarks, trade names).

\*\*\*\* IFRS for SMEs. 1st Floor, 30 Cannon Street, London EC4M 6XH, United Kingdom: IASB (International Accounting Standards Board). 2009. p. 14. ISBN 978-0-409-04813-1.

For airline operators and owners, keeping revenue-generating assets (such as the aircraft) in operation is a business imperative. Thus, it is not uncommon for MRO organisations to possess their own assets which will be given to the airline operator whilst they overhaul the operator's product. This phenomenon is increasingly becoming a market qualifier as it means that the airline operator or owner is still able to generate revenue whilst their product is being maintained. The temporary exchange of assets is an additional revenue generating stream for the MRO industry and increasingly becoming popular. Service and asset performance has become critical to success. Support packages offered by OEMs directly to airline operators and owners are also on the increase. This is increasingly leading to a paradigm shift in the approach to service engagements. There is a notable shift to performance-based services using contract vehicles such as performance-based logistics (PBL) or service-level agreements (SLA) – focusing on asset availability and reliability, as well as service performance in processes, supply chains and resources. These after-sale MRO-type packages offered by the OEM capitalise on both the *tangible* (such as spares and excess inventories) and *intangible* assets (such as Technical support and design data) that are more readily available to the OEM and thus producing a high-margin, dependable revenue stream for them. Both the OEM and the MRO depend heavily on service lifecycle management, enterprise asset management and plant maintenance to reduce service costs and increase asset availability and reliability<sup>††††</sup>. Therefore, to maximise the economic dimension of the business, it is essential to have accurate asset knowledge and execution efficiency.

The *intangible asset* forms the heart of the competitive advantage and performance (Vargo and Lusch 2004; Lusch and Vargo 2006a). This is based on the notion that the intangible assets are the assets that 'act' on the physical resource transforming them into the finished product or service. It is largely within the realm of the intangible assets that competitive advantage can be enhanced (Sreedhar and Hunt, 2007). Previous research by Barney (1991) introduced intangible assets as physical capital, human capital, and organizational capital. However other publications have extended this classification of intangible resources into financial (e.g., cash resources and access to financial markets), legal (e.g., trademarks and

---

<sup>††††</sup> Air Transport World - AEA chairman flags key MRO issues (Association of European Airlines (AEA) chairman Temel Kotil) [http://atwonline.com/mro/aea-chairman-flags-key-mro-issues?NL=ATW-04&Issue=ATW-04\\_20141007\\_ATW-04\\_269&sfvc4enews=42&cl=article\\_2&YM\\_RID=CPEN1000000422068&YM\\_MID=881](http://atwonline.com/mro/aea-chairman-flags-key-mro-issues?NL=ATW-04&Issue=ATW-04_20141007_ATW-04_269&sfvc4enews=42&cl=article_2&YM_RID=CPEN1000000422068&YM_MID=881) (accessed, Oct., 2014)

licenses), human (e.g., the skills and knowledge of individual employees), organizational (e.g., competences, controls, policies, and culture), informational (e.g., knowledge from consumer and competitive intelligence), and relational (e.g., relationships with suppliers and customers) (Hunt, 2004).

### 5.6.2 Economic Dimension – Capabilities

Capability is the ability to perform or achieve certain actions or outcomes through a set of controllable and measurable faculties, features, functions, processes, or services (Amartya, 1985). The capability of an organisation serves as the link between the economy dimension and the operational requirements to meet the strategic objectives in value creation and delivery. Most organisations comprise a combination of capabilities that are used in various combinations to create and deliver value (Barney, 1991).

Capability has also been referred to as Competencies by some authors (Day 1994; Hunt and Madhavaram 2006b). Whilst these two concepts are distinct, they are not dissimilar. For example, Sreedhar, and Hunt (2007) points out that whilst Winter (2003, p.991) defines an organizational capability as “...a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization’s management a set of decision option for producing significant outputs of a particular type...”; Heene and Sanchez (1997) define Competence as “...an ability to sustain the coordinated deployment of assets (anything tangible or intangible the firm can use in its processes for creating, producing, and/or offering its products to a market) in a way that helps a firm achieve its goals...”. Thus, because of the similar conceptualizations, Sreedhar, and Hunt (2007) posit that Capabilities and Competences may be equated and defined as “...socially complex, interconnected combinations of tangible basic resources (e.g., specific machinery, computer software and hardware) and intangible basic resources (e.g., specific organizational policies and procedures and the skills, knowledge, and experience of specific employees) that fit together coherently in a synergistic manner to enable firms to produce efficiently and/or effectively valued market offerings...” (Hunt 2000a, p.188).

While capability management is more advanced within military environments, the paradigm shift in the offerings from especially from OEMs (such SLA’s) are creating more awareness within the MRO community and bringing more emphasis to their capability management.

More emphasis on the capability management will lend towards helping the MRO outfit to develop solutions that focus on the management of the interlinking functions and activities in the organisation's strategic and current operational contexts. Furthermore, distilling the economic dimension into the key business decision areas, - assets and capabilities, it provides a better understanding of how to effectively integrate the total organisations ability to achieve strategic and current operational objectives. Armed with this understanding, the success of Lean adoption is significantly improved.

Whilst it is difficult to categorise Capabilities, Sreedhar, and Hunt (2007) were able to bring order to the study carried out by Collins (1994) and Day (1994) which suggests that Capabilities usually exists in three forms. These forms include:

1. **Inside-out Capabilities:** *These are abilities that help in performing basic functional activities of the organisation.*
2. **Outside-in Capabilities:** *These are abilities that help in dynamically improving the activities of the organisation.*
3. **Spanning Capabilities:** *These are the abilities involving strategic insights that can help organisations in recognizing the intrinsic value of their resources and in developing novel strategies ahead of their competitors*

In rapidly changing environments, all forms in which Capability exists, Zollo and Winter (2002) propose that "...Capability is a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness..." Except where crucial all forms of Capability will be referred to as Capability as they all lend towards enabling the organisation to modify itself so as to continue to produce, efficiently and/or effectively, market offerings for some market segment(s).

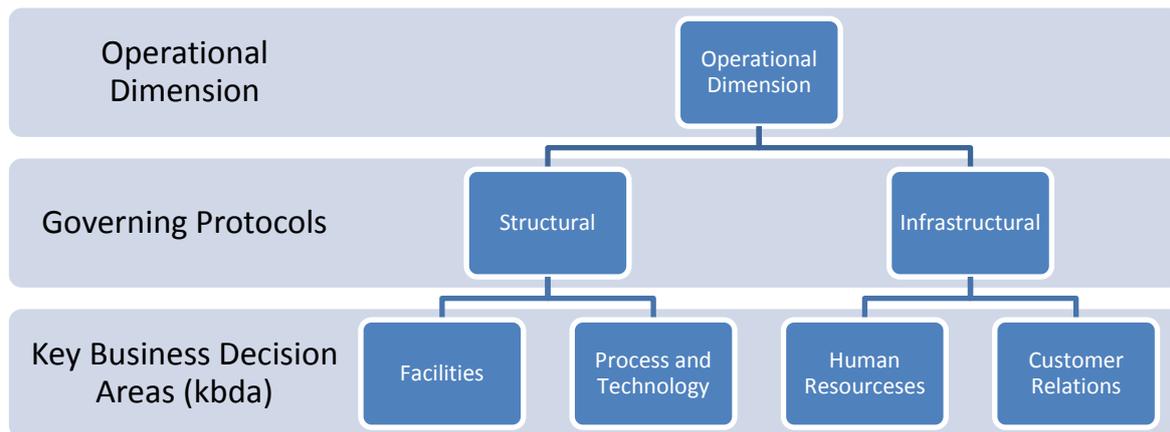
### 5.7 MRO Value Delivery System – Operation Dimension

At the operational level, this dimension represents an architectural configuration of the organisation. The focus is on internal processes and design of infrastructure that enables the firm to create value. Decision variables particular to the MRO industry include both production and service delivery methods, administrative processes, resource flows,

knowledge management, and logistical streams. Mayo and Brown (1999) refer to this dimension as the “design of key interdependent systems that create and sustain a competitive business.” This system is made of the value chain activities which the organisation engages in to deliver value. Lean philosophy has to be realised across all the dimensions of the value delivery system; however, it is within the system of value creation/delivery activities that the adoption of Lean is most visibly applied.

This component is called the configuration of value chain activities and represents the organisation’s actual architecture that generates value for customers by putting long-term normative (strategic) ideas into action (Richardson, 2008; Zott and Amit, 2010; Daft and Albers, 2011). As mentioned in the literature review presented in chapter 2, the MRO industry is a product-centric service environment and possesses elements that are typical of traditional manufacturing industry and traditional service industries. Hill (2000) suggest that whilst production operations are associated with elements such as product specification, quality conformance and delivery which translate into a set of internal performance metrics; service operations tend to be more biased toward associated with intangible and more subjectively assessed attributes (Baines et al., 2008). The MRO industry is more accurately represented as a subtle blend of transactional and relational metrics. This position is substantiated by Porter's concept of the value chain (Porter, 1985).

With the evolution of business approaches, there have been several contributions to develop relevant operation systems and their respective value chain activities. These contributions range from Ford (1922) through to the work on Lean systems by Womack et al., (1990). The starting point of operations systems formulation is always to understand customer value requirements (Baines et al., 2008). Similarly, Schroeder and Lahr (1990), Mills et al., (1995) to Hill (2000), all propose design processes that start with customer value dimensions using measures such as cost, quality and timeliness. Therefore, it seems appropriate that the identification of the key business decision areas within the MRO industry should follow the same approach in the creation and delivery of value.



**Figure 5.7: Understanding the aspects to the Operational Dimension to the MRO Value Delivery System**

### 5.7.1 MRO Operational System - Principal Constructs of the Key Business Decision Areas (kbda)

From the definition of the MRO industry as summed up by Al-Kaabi (2007) it becomes clear that the MRO *capacity* cannot be accurately defined solely within manufacturing or service terms alone as it seems to encompass aspects of both industries. For example, the conventional manufacturing industry could refer to MRO offerings in terms of its ‘remanufacturing’ functions; describing the main function of the MRO industry as responsible for the restoration of the product (aircraft) back to a state where it can perform its required design functions. Conversely, the conventional service industry could argue that the primary function of the MRO industry is to provide a ‘service’ in the form of aircraft maintenance to the aviation industry. It therefore follows that a compromise between the two perspectives may be more accurate in describing the MRO capacity. Therefore, it would not be out of place to refer to the aviation MRO industry as a ‘product-centric service’ industry; a description that seems to encompass elements of both the conventional Manufacturing and Service industries into one unit. The MRO capacity is made up of different functions with some more closely related to conventional manufacturing (or production) contexts while others are more popular in conventional service environments. The combination and interaction of these different functions is represented by the ‘Operations System’ of the MRO industry which will be evident in typical MRO organisations.

The operation system of a company is based on the subtle blend of the ‘transactional’ and ‘relational’ activities (Baines et al., (2009). These activities can also be represented as the

production and service characteristics of the organisation. Production characteristics tend to be configured on conventional principles focused on the physical transformation of product into finished goods. By contrast, the service characteristics focuses on the interaction of the non-physical systems connected by similar value propositions as the production operations through facilitation and mediation. These production and service characteristics can be distilled and grouped into the ‘Key Characteristics of Operation’ of the business. It is within these key characteristics of operation that strategic business decisions are often made. It is therefore expected that the introduction of Lean into the MRO industry should influence the decisions that are made within these key characteristics of operation. Understanding the influence of Lean within these areas would not only help in assessing the extent of Lean adoption, but will be crucial in validating Lean’s ability to mitigate typical MRO challenges.

Baines et al. (2009) established a comprehensive ‘Principal Model’ that represented a framework of key operational characteristics including the production-centred framework advocated by Hayes and Wheelwright (1984), Hill (2000); service-centred operation frameworks that were advocated for by Collier and Meyer (1998) and Silvestro et al. (1999). Across these two groups, 11 distinct key characteristics of operations were identified and divided into Structural and Infra-structural characteristics based on their production and service orientations as listed in Table 5.1.

Structural characteristics	Infra-structural characteristics
Process and Technology	Human Resources
Capacity	Quality control
Facilities	New Product/Service Range and introduction
Supply Chain Positioning	Performance measurement
Planning and Control	Supplier Relations
	Customer Relations

**Table 5.1: Characteristics of operation Baines et al. (2009)**

The achievement of ‘Leanness’ in a best-in-class company would largely be determined within the framework of these key characteristics of operation (Camp (1989); Heibeler *et al.*, (1998); Davies and Kochhar (2002)). The influence of Lean within these areas would be observable and as such, enable an assessment of the extent of Leanness in the different

processes within an organisation. It is important to note that popular usage of the term ‘Key Characteristics of Operation’ can also be represented as ‘Strategic Business Decision Variables’ (SBDV – similar to key business decision areas (kbda) of the organisation and thus, both terms will be used interchangeably except where intent and understanding is crucial. For the purpose of this study, the identified characteristics of operation refer to the following:

### 5.7.2 Structural Characteristics of Operation

The Structural characteristics of operation are:

#### 5.7.2.1. *Process and Technology*

This key characteristic of operation largely represents the physical resources and technologies that are used within operations Baines et al. (2009). This deals with automated systems and varying range of technology, information systems and databases to enhance product conformance, efficiency, communication and customer interaction. It also deals with production (shop-floor) layout and processes. The challenge within the product-centric environments akin to the MRO industry is the ability to exploit a range of technologies throughout operations to achieve efficiency in production and effectiveness in service delivery

#### 5.7.2.2. *Capacity*

This characteristic of operation deals with how production capacity should be matched to demand in order to ensure optimum resource utilisation (Hayes and Wheelwright, 1984). The main emphasis in this strategic business decision area is on the interaction between Human Resources, Technology and Supply Chain to match demand. For example, Baines et al. (2009) suggests that product-centric service operations are characterised by multiple customer touch-points each of which can generate varying capacity demand signals necessitating differing forms of response from the host organisation. Thus, the fluctuating demand experienced by the MRO industry should suit multiple customer “touch points” that would foster the need to operate with differing levels of capacity utilisation.

#### **5.7.2.3. Facility**

This key characteristic of operation typically deals with the choice of production sites, their location and specialisation (Hayes and Wheelwright, 1984). For example, this study will be keen to explore if the MRO industry exploits economies of scale by bringing together and centralising production activities that maximise available resources to both accommodate and enhance customer experience (Chase and Garvin, 1989). This does not limit production to a single site. It is common for Product-Centric Service organisations to re-organise their business into networks of smaller business units or multiple field facilities within close proximity to the customer to aid quicker response and deliver an overall better service.

#### **5.7.2.4. Supply Chain Positioning**

This covers the range of activities carried out by the company and how it relates to outsourcing, in-sourcing, subcontracts, Make vs Buy decisions. The positioning and control of an organisation's supply chain is dependent on its production footprint is usually centred on its core competencies. Product-centric service organisations typically tend to have control over the cost and quality by continuous vertical integration whilst positioning itself to become less dependent on broad in-house capabilities and thus engage partner organisation in delivering value (Prahalad and Hamel, 1993; Davies, 2004).

#### **5.7.2.5. Planning and Control**

This relates to the flow of materials in and through the company using different production planning models. More popular models include Enterprise Resource Planning (ERP), Materials Requirements Planning (MRP), Optimised Production Technology (OPT), Period Batch Control (PBC), and Kanban. There is a focus on the optimisation of product availability and interaction between information capacity and stock (Ranky, 1983; Hill, 2000).

### **5.7.3 Infrastructural Characteristics of Operation**

The Infra-structural characteristics of operations are:

#### **5.7.3.1. Human Resources**

This refers to integration of the workers into the operation system. This involves the sub-division of labour and fragmentation of process with increased emphasis on worker skills,

defined routines, training, motivation, attitudes, values and culture of the organisation in sufficiently satisfying customer requirements (Chase, 1978).

#### **5.7.3.2. *Quality Control***

Efficient production operations have utilised Lean principles and techniques to control quality by achieving product conformance and the minimisation of waste in materials and resource usage (Womack et al., 1990). This business decision area extends beyond the product to include appropriate measures that improve on the customer's perception of acceptable service (Baines et al., 2009). Examples of tools that have been employed in these areas include Statistical Process Control (SPC), Statistical Quality Control (SQC).

#### **5.7.3.3. *New Product / Service Introduction***

This business decision area involves the configuration of the operation system to deal with the introduction of new product or services (Hill, 2000). Although several methodologies for new product introduction are extensively discussed by many authors in conventional manufacturing contexts, common practice is to allow for ample test to be carried out before the product is released to the market (Womack et al., 1990; Haque, 2003; Oppenheim, 2004); the testing and refinement of new services are carried out 'in the field' with the customer as they are usually tailored to customer expectations that may exist at different levels of consciousness (Miller et al., 2002).

#### **5.7.3.4. *Performance Measurement***

This refers to the performance measuring approach of the organisation. Although, traditional performance metrics are generally measured against Cost, Quality and On-time delivery; Product-centric Service environments also feature metrics that tend to use different customer and employee satisfaction and business success criteria (Morris and Johnson, 1987; Lewis, 2004; Gebauer and Friedli, 2005). This study will be keen to evaluate the influence of Lean in the area how it relates to the motivation for Lean adoption. These approaches may involve the use of tools such as machine utilisation, worker utilisation, WIP, Door-Door time.

#### **5.7.3.5. *Supplier Relations***

This refers to how the operation system is configured in the sourcing of resources and materials. Effective management of the supply chain is critical for efficient and effective production operations (Lamming, 1993). To be effective, it is important to align supplier relations in both internal and external supply chains. Other approaches may involve single sourcing to multi sourcing or even the integration of external and internal supply chains. Whatever the approach, the responsiveness of supply chain in meeting customer expectations is critical

#### **5.7.3.6. *Customer Relations***

This key characteristic of operation refers to the balance between the transactional aspect of production and the relational aspects of the operation system. Whilst the transactional aspects generally tend to focus on improving internal operational efficiency, it is crucial to pay equal attention to the relational aspect of the operation system in building and maintaining relationships with customers (Verstrepen et al., 1999). This study will also assess what influence of Lean has in the interaction between the MRO industry and the end customer (airline operators).

The delineation of the MRO VDS provides a means through which the Strategy, (business) Processes and (business) activities can be aligned to provide crucial harmony between dimensions and in practice, organisational layers. The VDS signifies a mediating construct between the fulfilment of competitive aspirations (strategic goals) and objectives including the creation of the essential economic value. Chesbrough & Rosenbloom (2002) suggests that the VDS unlocks latent value and creates a heuristic logic that connects potential with the realisation of competitive aspirations.

### **5.8 Critical Resources of the MRO Value Delivery System.**

This section focuses on the critical resources factors associated to the MRO value delivery system (VDS).

Regardless of the industry or context of implementation, there are four critical resources which serve as fundamental pillars in supporting the value delivery system (Sawhney et al., 2010). These pillars are:

- Personnel
- Equipment
- Material
- Scheduling

‘**Personnel**’ refers to the workforce; their capabilities and skills. ‘**Equipment**’ refers to the primary and auxiliary equipment (inclusive of assets) utilised in value delivery systems. ‘**Materials**’ refers to the raw materials, works-in-process (WIP), and finished goods involved with operations. ‘**Scheduling**’ refers to the ability to accurately forecast, plan and schedule a production system to operate efficiently. The parameters within each of these resources albeit similar to the manufacturing context, are distinct and in some cases more complex within MRO. Evidently, a direct transference of Lean from one context to another may not result in successful Lean realisation to achieve strategic goals and competitive advantage. For example, although the induction of the product for its maintenance input can be more easily planned (similar to manufacturing environment), it is relatively more difficult to forecast the actual activities involved with the actual maintenance input itself. This is due to the fact that the actual condition of the product is not known until after troubleshooting which may affect the lead time (turn-around-time TAT). The ability to successfully realise MRO value proposition is hinged on the Personnel, Materials, Equipment and Schedule associated with the VDS.

Sawhney (et al., 2010) also suggested that in order to describe a value delivery system to be successful, it must be *reliable*. IEEE defines reliability as “...*the ability of a system or component to perform its required functions under stated conditions for a specified period of time...*” (IEEE: Std 610.12, 1990). According to this definition, a reliable VDS should exhibit the three characteristics highlighted. This will mean that a reliable VDS system is (in terms of “Required Function”):

- **Personnel** must be available and qualified to perform standard operating procedures so that product quality and delivery requirements are met.

- **Equipment** should not unexpectedly fail and, if it fails, the repair time should be minimized.
- **Materials** are delivered in the right quantity at the right time and at the right location.
- **Schedule** is attained without variance, rescheduling and expediting.

In terms of the “Stated Conditions”:

- **Personnel** will incur fluctuations in availability and performance.
- **Equipment** will incur unplanned events, such as extended downtime or performance below the given specification.
- **Material** availability and quality will vary due to volatility in the market.
- **Schedule** must adapt to meet a customer-oriented market with short-term fluctuations in demand.

The reliability of the value delivery system is hinged on these four critical resources. As such, continuous benchmarking is an essential in recognising performance gaps with each resource. With sufficient performance benchmarking, an organisation is able to monitor its competitiveness and initiate improvement schemes to areas with increasing performance gaps. In return, this will aid in determining suitable process intent, and will also assist in minimising non-value adding activities and optimizing value-adding activities (Yung & Chan, 2003).

## 5.9 Overview and Chapter Summary

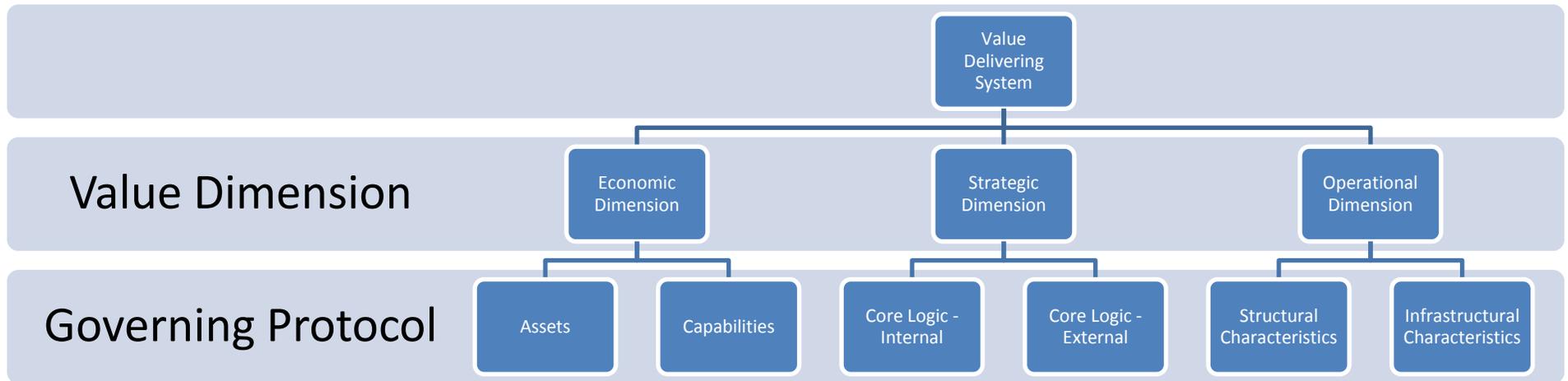
Competitive advantage can emerge from superior execution of particular activities across the organisation’s value delivery system (Hunt, 2000) and this chapter detailed the various aspects of the value creation network and its various dimensions (Section 5.2 and Section 5.4). It is crucially important to lay these foundations particularly as it pertains to the MRO industry (Section 5.5) as it represents the context within which is to be realised. Literature review suggests that there cannot be a direct transfer of Lean from on business environment to another and the successful realisation of Lean manufacturing context has to be realised within the MRO context. Hence it was vitally important that a more accurate understanding

of the MRO business environment be established to aid the successful adoption of Lean philosophy.

The development of the MRO VDS helps to first understand the MRO context at different levels: Value Dimension; Governing Protocol, Key Business Decision Areas (as shown in Figure 5.8). The prevalent focus of Lean's application (as depicted from the status of MRO Lean engagements in Chapters 2 and 4) show that its focus has been directed mainly to a operational dimension and hence, whilst recording significant benefits, these benefits may not translate into competitive advantage. This research proposes that it is the application of Lean to all aspects of the VDS that correctly appropriates Lean efforts to enhance competitive advantage. This understanding has led to the realisation that Lean thinking is not only applied to the shopfloor where waste is more easily seen, but this thinking is sustained when it is applied to even the strategic and the economic dimensions of the business. This chapter presented the three main dimensions of the MRO value delivery system which includes:

- The corporate core logic as the Strategic level,
- The assets of a firm as its Economic Level and
- The configuration of value chain activities as the Operational level.

This component design is surmised into the system through the MRO is able to create and deliver value. It is also forms the framework within Lean is to be realised. With this chapter laying the foundation and developing the framework, the following chapter operationalises this concept with a case study. This chapter completely satisfies objective 2 of this research.



**Figure 5.8: Understanding the aspects to the MRO Value Delivery System**

## 6. COMPETITIVE ADVANTAGE AS IT PERTAINS TO MRO

Based on the outcome of the Phase 1 of this research which sought to establish the status of MRO Lean engagements (via literature review – chapter 2; and empirical study - chapter 4) it was noted that “...*clarity is still needed with how Lean can be applied within the aviation MRO context to facilitate competitive advantage...*” Whilst the positive effects of Lean application especially with regards to efficiency was noted, it remained unclear as to how these benefits translated into competitive advantage. Although improvement may be recorded within operations, this does not translate into sustainable increase in either its profitability or market share. Thus, if the intention of Lean application within MRO industry is to enhance competitiveness, it became necessary to understand what competitiveness comprised of especially as it pertained to the MRO industry. Indeed competition is described to be at the core of the success or failure of any organisation (Porter, 1985). Porter suggests two parts to competitiveness: the ‘attractiveness of the industry’ and the ‘determinants for relative positioning’ within the competitive environment. As such, presented in this chapter is the structural assessment of the MRO industry (Section 6.1) with regards to the forces that determine competitiveness. The role of Lean in achieving competitive advantage within this context is then presented (Sections 6.2 to 6.4) and the competitive routes within the MRO industry are presented in Sections 6.5 through to 6.7. Competitive priorities and the performance measurement are elucidated in Sections 6.8 and 6.9 with a chapter summary in Section 6.10.

.

## 6.1 Structural analysis of the MRO industry.

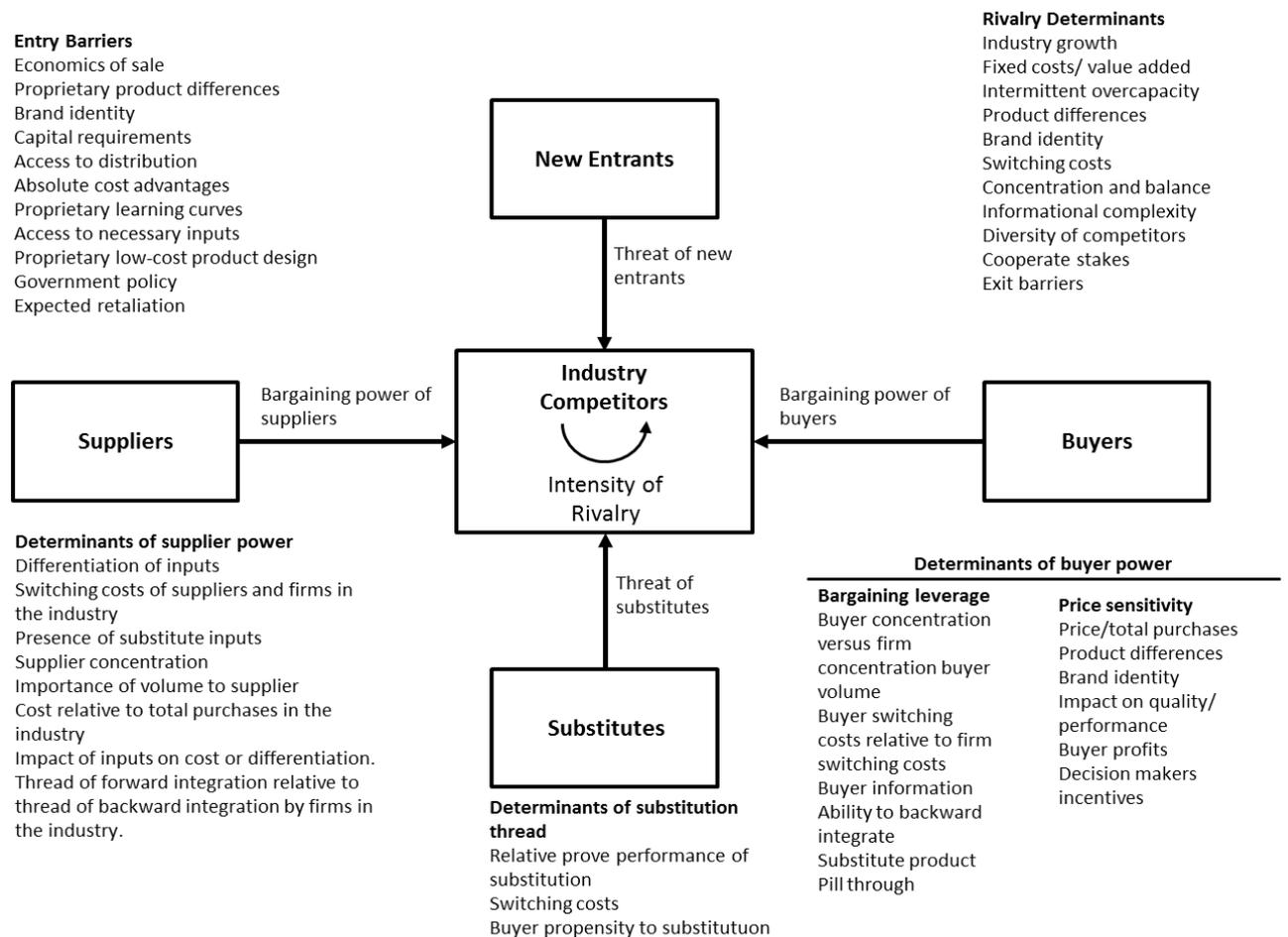
The first fundamental determinant of a firm's profitability is industry attractiveness (Porter, 1985). Although air travel demand has a secondary effect on the MRO market value (Miller & Park, 2004), the global MRO industry still generated revenues of around \$111 billion in 2009 (Srinivasan et al., 2014) during a period of global financial crises. With the International Monetary Fund (IMF) posting figures for 2013 that show that only 70 percent of countries in the world having a gross domestic product (GDP) of less than \$111 billion, achieving and sustaining competitive advantage is a very attractive proposition for MRO organisations. Porter (1985) suggests that achieving and sustaining competitive advantage grows out of a sophisticated understanding of the rules of competition that determine an industry's attractiveness. As such, this chapter will seek to present an understanding of the competition comprises within the aviation MRO context.

As described in chapter 2, the MRO landscape is characterised by a large number of suppliers. These suppliers range from the relatively larger organisations such as the two major original equipment manufacturers (OEM) – Boeing and Airbus, to also include maintenance division of large commercial airlines such as Lufthansa Technik and Delta TechOps, American Airways-MRO (AA-MRO). The competitive forces within the MRO context will affect all organisations within the MRO value chain regardless of size. Although there is a degree of exposure to the global market conditions of the aviation industry, the MRO is more resilient because MRO industry revenues are not directly affected by the cost of crude oil and there is a constant need for maintenance due to safety and government regulations (Srinivasan et al., 2014). Unlike in other industries, where safety could be considered as order-winning criteria, safety and regulatory restrictions in the aviation MRO context are order-qualifying criteria. Although Srinivasan et al., 2014 suggests that these safety and regulatory specifications could have a negative effect on global competitiveness because of the additional cost and time restrictions on customers, these specifications tend to apply to all suppliers within the MRO value chain and in some cases, they could even serve as an order-winning criterion.

Porter (1985) suggests that industry profitability is not a function of what the product looks like or whether it embodies high or low technology, but of industry structure. Based on this, Porter suggests that there are five forces which competitiveness of an industry. These include:

1. The entry of new competitors;
2. The bargaining power of buyers;
3. The threat of substitutes;
4. The bargaining power of suppliers;
5. The rivalry among the existing competitors.

Collectively, these five competitive forces determine the industry profitability because they influence the prices, costs, and required investment and ultimately, the relative competitive position of the organisation.



**Figure 6.1: Five competitive forces that determine the industry profitability (Porter, 1985).**

Developing the understanding of these forces as it pertains to the aviation MRO industry will ensure that Lean is correctly appropriated within the context of the competitive boundaries as organisation are able to more accurately assess the intensity of competition and the source of

this competition. The following sections of this chapter describe in more detail the competitive forces affecting the aviation MRO industry.

### 6.1.1 The threat of New Entrants

Competitive advantage is not only a function of the *value* produced by an organisation but also a function of the structure of the industry (Porter, 1985). One of the key forces that shape the structure of the industry is the **threat of New Entrants**. Porter (1980) describes the threat of new entrants as the threat new competitors pose to existing competitors in an industry. The more profitable an industry is, the more attractive it is to new entrants. If its barrier to entry is thus low, the threat posed to firms already competing in the market is higher which subsequently affects the competitive environment and makes it even difficult for existing firms to achieve profitability. Achieving competitive advantage in such situations becomes even more difficult. Within the MRO context, Lester & Bradford (2009) propose that the threat of new entrants is the threat posed to the established industry competitors by new firms entering either through *acquisition* or *start-ups*.

The threat of new entrants via **acquisition** materialises through either the purchasing of a current competitor (to expand market share), or by purchasing multiple firms and creating a powerful conglomerate. The threat of new entrants via **start-up** firms materialises with significant investment capital exploiting state-of-the-art technology to capture market share (Lester & Bradford, 2009). Lufthansa Technik has been able to rapidly increase their MRO market share through acquisition and also start-ups. For example, the Landing Gear Product Division started from one site based in Hamburg, Germany to become a conglomerate of several firms across the UK and Americas with the purchase of competitor firms. In Jun of 2016, Lufthansa Technik opened a new start-up facility in Aguadilla, Puerto Rico using state-of-the-art technology to increase its MRO market share in the Americas<sup>\*\*\*\*</sup>.

The threat of new entrants affects the competitive environment for the existing competitors and influences the ability of existing firms to achieve profitability. Regardless of how the

---

<sup>\*\*\*\*</sup> Lufthansa Technik Puerto Rico starts operations. ([https://www.lufthansa-technik.com/press-releases-content/-/asset\\_publisher/9Mf5/content/id/1697005](https://www.lufthansa-technik.com/press-releases-content/-/asset_publisher/9Mf5/content/id/1697005)) Accessed in August 2016).

threat of the entrant is materialise, Porter (1980) provides an insight to the barriers that entrants must overcome to become successful. These barriers include:

- **Economies of scale:** This refers to the cost advantage per unit experienced within environments characterised by high-volume production. Economies of scale could serve as a barrier for new entrants because in order to be competitive, they will have to match the cost per unit that existing companies already have.
- **Product differentiation:** This refers to the brand distinctions that new entrants may have to achieve in order to be competitive with already established companies.
- **Capital requirements:** This refers to the significant investments required by new entrants in order to be able to compete with already established firms. These investments range from capital investments to research and development to marketing and even personnel investments.
- **Other Cost Advantages:** Apart from the cost benefits from the economies of scale, other costs such as the learning cost from years of business experience, to even strong Supplier knowledge and understanding could serve as a barrier that new entrants may not be able to initially produce.
- **Switching costs:** This refers to the costs associated with a customer moving from one company to another. Although this cost is usually associated with the building of new business relationships, other cost such as geographic constraints and even contractual agreements are captured in this barrier to new entrants. If these costs are high, they could serve as a barrier for new entrants.
- **Distribution Networks:** This refers to the distribution networks which new entrants will require access to. Existing firms would already have access to these networks and new entrants may have to pay a premium in order to get the same access to these networks.

- **Government policy:** This refers to the restrictions imposed through government policy which could be in the form of, laws, codes, permits and licenses that offers barriers to new entrants.

With the understanding that the threat of new entrant serves as a key force in shaping the competitive structure of the industry, it is important to assess the effects these threats may have within the different sectors of MRO. For example, whilst the growth forecast of the MRO industry as a whole might make it a very attractive industry, the capital requirements to for new entrants may vary from one MRO-sector to another (Engine Sector to Component Sector). The structural analysis of the MRO industry as presented from Table 6.7 to Table 6.7 provides an overview of the threats posed by new entrants as it affects the different MRO sectors.

The protocols through which these threats are derived are based on literature reviews which have are vetted by industry professionals and senior executives within the Lufthansa Technik Group. Whilst these views may not be representative of the industry as a whole, they represent the threats faced by Lufthansa Technik which has a substantial market share within all sectors of the MRO industry. For example, the Lufthansa Technik Landing Gear Services based in London, UK, is the world's leading MRO provider for Boeing Landing Gear services as it has won and carried out over 80 percent of all available Boeing 777-300ER Landing Gears due for service. Similarly, the extensive Line and Heavy Maintenance network within the Lufthansa Technik brand with significant sites in Europe, the Americas (including the US), Middle East and Asia make them one of the leading competitors in the market. Lufthansa Technik also offers its own bundled aftercare programme (Total support) which is an integrated MRO service option to their customers<sup>§§§§</sup>.

---

<sup>§§§§</sup> Lufthansa Technik Total Support Services (<http://www.lufthansa-technik.com/total-support>)

	<b>Component</b>	<b>Engine</b>	<b>Line Maintenance</b>	<b>Heavy Maintenance</b>	<b>Avionics</b>	<b>Modification / Retrofit</b>
<b>Economies of Scale</b>	The MRO industry is large and it is growing – estimated MRO spending to exceed \$140 billion by 2017. This makes this the MRO industry attractive and the benefits of economies of scale are high 2017 (Srinivasan et al., 2014).					
	In line with the forecast for the industry, the structure of the Component sector makes it a very attractive industry. As such, component manufacturers are also expanding their capabilities into the maintenance and repair outsourcing (MRO) service area (KPMG, 2016).	The increase in bundled aftermarket support packages by OEM (such has TotalCare by Rolls Royce) provides more opportunities for new entrants who are not traditional MRO organisations (Michaels, 2007). OEMs could leverage the success of such business models as a means of entering the market	Growing demand for air travel, massive backlogs of new aircraft orders, and a slowly resurging business jet sector makes this sector very attractive for new entrants to leverage on economies of scale (KPMG, 2016).	With airlines opting for next-generation, more fuel-efficient, technologically advanced aircrafts, there is an increased focus on replacing older fleets which makes this sector less attractive for new entrants. It is estimated that about 40 percent of all new aircraft deliveries will be for replacement purposes*****	MRO organisations that specialise in military applications are able can leverage on dual-use or similar products and employ the experience to realise the benefit of economy of scale (KPMG, 2016).	Products that fall within this category are usually fewer in number and as such, the structure of this sector may not be as attractive especially with regards to reaping the benefits of economies of scale††††

**Table 6.1: Threat of New Entrants as it applies with ‘Economies of scale’**

\*\*\*\*\* Alix Partners, Bloomberg, Aerospace Industries Association and CSI Market

†††† Ascend, company reports, and J.P. Morgan estimates

	Component	Engine	Line Maintenance	Heavy Maintenance	Avionics	Modification / Retrofit
<b>Product Differentiation</b>	<p>Whilst it is difficult to offer a differentiation in the product itself, new entrants may be able to offer lower cost by utilizing Part Manufacturer Approved (PMA) parts as a way of differentiating themselves and gaining entry into MRO industry. The FAA’s Parts Manufacturer Approval (PMA) process allows non-OEMs to reverse-engineer some OEM parts and sell them at a significant discount (Carpenter &amp; Henderson, 2008). Low product cost presents one method of decreasing the barriers to entry</p> <p>Also the bundled aftermarket support packages by OEMs provides the OEMS with and improved position to provide discounts to the customer on original purchases when made with an accompanying service contract (Carpenter &amp; Henderson, 2008; Lester &amp; Bradford, 2009). However, whilst this may increase the competitive position of OEMs in the MRO market, they could also increase the barrier of other new entrants who may not be abler to provide such service.</p>					
	<p>Whilst quality has largely remained an order-qualifying criterion in the aviation MRO industry, the quality performance status achieved by some agencies may serve as a way of differentiation within the MRO market. The brand recognition of these agencies could serve to increase the barrier for new entrants.</p>					
	<p>OEM’s within the <b>Component</b> and <b>Engine</b> sectors are willing to compromise on prices for new products with the intent to leverage on the highly-lucrative long-term replacement parts and MRO business. Whilst PMA parts are becoming more familiar, the ability of OEM to be able to offer this compromise could increase the barrier for new entrants (KPMG, 2016).</p>					

**Table 6.2: Threat of New Entrants as it applies to ‘Product differentiation’**

	<b>Component</b>	<b>Engine</b>	<b>Line Maintenance</b>	<b>Heavy Maintenance</b>	<b>Avionics</b>	<b>Modification / Retrofit</b>
<b>Capital Requirement</b>	<p>Maintenance facilities for heavy industry-crafted aircraft components, (e.g. Landing Gear, Engines and Airframes) require significant capital investments for new entrants (Carpenter &amp; Henderson, 2008). High capital investment requirements lead to increased barriers to entry (Lester &amp; Bradford, 2009).</p> <p>Specialized equipment for highly technical repairs and testing (electronics, avionics and engines) requires large capital investments by new entrants (Carpenter &amp; Henderson, 2008). High capital investment requirements lead to increased barriers to entry.</p> <p>The inventory required by MRO to support quicker TAT requires significant operating capital. High operating capital requirements lead to increased barriers to entry (Srinivasan et al., 2014).</p>					

**Table 6.3: Threat of New Entrants as it applies to 'Capital Requirement'**

	<b>Component</b>	<b>Engine</b>	<b>Line Maintenance</b>	<b>Heavy Maintenance</b>	<b>Avionics</b>	<b>Modification / Retrofit</b>
<b>Other Cost Advantages</b>	<p>Access to OEM documentation and technical expertise necessary to effect repairs requires new entrants to establish both business and working relationships with these OEMs. The information necessary to conduct repairs often is proprietary and requires licensing to access. The cost of licensing access increases the barriers to entry (Carpenter &amp; Henderson, 2008; Lester &amp; Bradford, 2009).</p> <p>Industry certifications such as ISO 9000 and AS9100 require large initial capital investments in manpower, training and equipment. Rigorous industry certification processes present increased barriers to entry (Lester &amp; Bradford, 2009).</p> <p>MRO activities are usually specialised and labour-intensive and as such the operating capital required to attract highly-skilled work force could serve as a barrier to entry (Carpenter &amp; Henderson, 2008; Lester &amp; Bradford, 2009).</p>					

**Table 6.4: Threat of New Entrants as it applies to 'Other Cost Advantages'**

	Component	Engine	Line Maintenance	Heavy Maintenance	Avionics	Modification / Retrofit
<b>Switching Cost</b>	<p>Due to the complexity and number of specialised components, switching to new suppliers can represent significant costs to the customer<sup>****</sup>. High switching costs increase barriers to entry.</p> <p>Apart from the financial cost, the risk associated with switching contracts especially with newer agency that may not have the same brand recognition in terms of quality and TAT performance could serve as a barrier for new entrants. New entrants are usually perceived to pose greater risk than established firms (Lester &amp; Bradford, 2009).</p>					

**Table 6.5: Threat of New Entrants as it applies to 'Switching Cost'**

---

<sup>\*\*\*\*</sup> Global Aerospace Market Outlook and Forecast. AIAC Phase 3 Report, (October, 2010)

[http://aiac.ca/wp-content/uploads/2015/11/AIAC-Phase-3-Report\\_FINAL.pdf](http://aiac.ca/wp-content/uploads/2015/11/AIAC-Phase-3-Report_FINAL.pdf) (Accessed in 2016)

	<b>Component</b>	<b>Engine</b>	<b>Line Maintenance</b>	<b>Heavy Maintenance</b>	<b>Avionics</b>	<b>Modification / Retrofit</b>
<b>Distribution Networks</b>	<p>With most major commercial airlines having now disposed of their “in-house” MRO capabilities, the MRO market has largely consolidated into geographic centres. New entrants will thus have to locate their facilities at strategic sites to able to compete with established agencies. This could serve as a barrier for new entrants. However, with locations where the labour cost are relatively cheaper new entrants making inroads into the MRO market, can leverage and invest in these lower-cost centres in order to remain relevant in not only the commercial, but also the general aviation sector (KPMG, 2016)</p> <p>The strategic geographic location of MRO agencies bring with it inherent logistical challenges with supplier networks and administrative functions to provide the necessary support to the customer. The scope and complexity of these logistical challenges in present barriers to new entrants (Lester &amp; Bradford, 2009). Inclusive with these logistic challenges are costs associated with AOG support and the shipping cost to-and-from the supplier and customer base.</p>					

**Table 6.6: Threat of New Entrants as it applies to ‘Distribution Networks’**

	Component	Engine	Line Maintenance	Heavy Maintenance	Avionics	Modification / Retrofit
<b>Government Policy</b>	<p>Whilst the FAA and EASA Approval are general recognised across the globe, some national aviation authority still require MRO agencies to get government certification.</p> <p>Similarly, some national labour laws put restriction on the amount of work that can be outsourced out of the country. Organisations may have to collectively bargain with unions before sending work overseas.</p> <p>Many government contracts are let on a lifecycle basis and firms receiving these contracts retain the right to repair work on certain components throughout the life of the airframe programme<sup>§§§§§</sup>. Existence of lifecycle maintenance contracts decreases the number of available contracts and, therefore, increases barriers to entry.</p>					

**Table 6.7: Threat to MRO competitive structure: New Entrants.**

<sup>§§§§§</sup> Federal Acquisition Regulation (March, 2015). General Services Administration, Department of Defence, National Aeronautics and Space Administration

<https://www.acquisition.gov/sites/default/files/current/far/pdf/FAR.pdf>

New entrants into the MRO industry experience a wide variety of barriers to entry ((Lester & Bradford, 2009). Aircraft manufacturer as well as airlines (such as Delta) have recognized the high margins and growth potential in aftermarket and have made acquisitions and investments to grow their aftermarket capacity including establishing dedicated groups to part-out aircraft, maintaining an extensive pool of used serviceable materials and internal engineering capabilities for repairs (KPMG, 2016).

The engine and component manufacturers are also expanding their capabilities into the maintenance and repair outsourcing (MRO) service area. Grant McDonald of the National Sector Leader of Aerospace and Defence at KPMG (Canada) is quoted as saying that there has been “...*significant acquisitions of MRO providers by the OEMs and it’s pretty clear that Airbus and Boeing are both looking to secure some of the ‘long-term annuity’ that can be achieved through the MRO sector...*” As such, Grant reckons that there is “...*likely to be further consolidation in the market as the bigger players start to sniff out deals that could help improve their footprint and create greater economies of scale.*” With high barriers to entry in this sector (such as high capital costs for inventory, the need for FAA certifications and the need to be close to the customer) ***it is unlikely that any new competitors will enter the market any time soon...*** However, with the industry successful firms may be able to find a niche market or create cooperative alliances through consolidation so as to grow their footprint through acquisition. This could become a lucrative option for Private Equity investors who may be attracted to the high margin potential, high levels of inventory, and the fragmented nature of the sector.

### 6.1.2 Bargaining Power of Buyers (Consumers)

The bargaining power of the buyer or consumer has a significant effect in shaping the competitive landscape and structure of the MRO industry. This is because the bargaining power of the buyers can affect the competitive environment for the producer and as such influence the seller’s ability to achieve profitability (Porter, 1980). This influence the buyer has on the competitive environment can result in a situation where considerable pressure could be exerted on producers in the form of lower prices or improved quality which could add to the (production) cost of the seller. Whilst a buyer with higher market influence could

make the industry more competitive and decrease profit potential for the seller a buyer with lower market influence could make the industry less competitive and increases profit potential for the seller.

“The power of each of the industry’s important buyer groups depends on a number of characteristics of its market situation, and on the relative importance of its purchases from the industry compared with its overall business” (Porter, 1980). Porter explains that consumers hold significant power over an industry if (they are):

- **Concentrated** (or purchases in large volumes). Large volume buyers are able to exert more pressure especially if the industry is characterised by significant fixed cost (as it is the case for the MRO industry).
- Their purchases represent a **significant fraction of buyer’s costs**. The buyers are likely to shop for a favourable price and purchase selectively. Conversely, buyers are usually less price sensitive in industries where the product sold is a small fraction of buyers’ costs.
- The products **purchased from the industry are undifferentiated (Standard offerings)**. Buyers are able to seek alternatives in cases where there is less differentiation in the offering of the industry.
- **Low switching costs**. Similar to the case made for industries with undifferentiated products (offerings), it gives more potency to the bargaining power of the buyer if the switching costs are low.
- **Low Profits**. There is more incentive to lower its purchasing costs if the profits are low. This lowering of the purchasing cost will also give more potency to the bargaining power of the buyer (and vice versa).
- There is a **credible threat to backward integration**. The ability of the buyer for backward integration by a buyer could serve as leverage in bargaining with the seller.

- **Quality is unimportant** to the buyer's product/services. There is a generally a direct link between the critical requirement of quality to the buyer's product/offering and its bargaining with the seller.
- The **buyer has full information about the seller's industry**.

The buyers of aviation MRO are as described in Section 2.4 (and they range from Military operators to Air Ambulances). Based on the aviation industry trends, the following paragraphs provide an overview of the forces exerted on the MRO industry based on the *bargaining power of the buyer*. An overview is presented because the bargaining power of buyer is similar across all MRO sectors. Similarly, whilst this discussion assesses the competitive structure of the MRO context, it is done from the perspective of the buyer and their influence on shaping the competitive environment. Based on this, the bargaining power of the buyer can be divided into two large groups – Military and Commercial. Both of these groups have distinct bargaining powers that shape the competitive structure of the industry. The key features of the bargaining powers are presented in Table 6.8

Military	Commercial
<p>Military MRO services are purchased by government military aviation enterprises which lead to an <b>increased concentration</b> and integration of customer base. This concentration gives more leverage to the buyer and a strengthened control over the industry (Lester &amp; Bradford, 2009).</p>	<p>Purchasers of commercial MRO services are not limited as they are with military purchasers and as such, the concentration effect of the buyer bargaining power is not as potent. With the growth of the commercial MRO is closely tied to the expansion of airline capacity and utilization levels and with the forecast predicting significant growth, the concentration effect of the <b>buyer’s bargaining power is likely to decrease</b> (KPMG, 2016).</p>
<p>Military aviation enterprises have few options for maintenance; however, this has occurred because these enterprises have <b>backward integrated</b> into the military MRO market (Lester &amp; Bradford, 2009). The <b>threat for backward integration is very credible</b> within military MRO landscape.</p>	<p>Significant structural change within the commercial MRO landscape has led to an increase in outsourcing of MRO activities. Airlines (who used to maintain their own maintenance and repair operations) have moved towards outsourcing this service<sup>*****</sup>, allowing them to diversify their aircraft fleet based on the specific route requirements rather than the desire to streamline maintenance costs (KPMG, 2016). Thus, the <b>threat for backward integration is not as credible</b> as it is with military MRO.</p>

(This Table is continued on the next page.)

\*\*\*\*\* Keep them flying. (IBM Global Business Service) [https://www-935.ibm.com/services/us/gbs/bus/pdf/gbw03020-usen-00\\_keep\\_flying.pdf](https://www-935.ibm.com/services/us/gbs/bus/pdf/gbw03020-usen-00_keep_flying.pdf)

Military	Commercial
<p>Military aviation enterprises set the standards required for maintenance on their aircraft and require full disclosure of all expenditures thereby giving them full information which inherently <b>increases the bargaining power</b> of the buyer<sup>+++++</sup>.</p>	<p>The standards for commercial MRO are set by the OEM and not the airline operators and apart from customer audit to check that the MRO agency is in compliance with OEM standards, commercial MRO are not required by law to provide full disclosure to the customer. The bargaining power of the buyer (customer) is not as strengthened as it is with military enterprises.</p>
<p>Operations, maintenance and personnel account for over 70 percent of the global defence budget. For example, the U.S. military spent \$24.3 billion, out of a \$379.9 billion defence budget, on aircraft maintenance in 2004 (Lester &amp; Bradford, 2009). This represents close to 16 percent spend on MRO services. Due to the proportion of funds spent on MRO it is safe to assume that the Department of Defence (DoD) will have an <b>increased bargaining power</b> due to DoD's <b>prices sensitivity</b>.</p>	<p>Similar to commercial airlines on averaging 13 percent of their total expenditures on MRO services<sup>+++++</sup> (Srinivasan <i>et al.</i>, 2014) and similar to military aviation context, the buyers will also have an <b>increased bargaining power</b> due to DoD's <b>prices sensitivity</b>.</p>

(This Table is continued on the next page.)

<sup>+++++</sup> Federal Acquisition Regulation, General Services Administration, Department of Defence, National Aeronautics and Space Administration

<https://www.acquisition.gov/sites/default/files/current/far/pdf/FAR.pdf>

<sup>+++++</sup> Keep them flying. (IBM Global Business Service) [https://www-935.ibm.com/services/us/gbs/bus/pdf/gbw03020-usen-00\\_keep\\_flying.pdf](https://www-935.ibm.com/services/us/gbs/bus/pdf/gbw03020-usen-00_keep_flying.pdf)

Military	Commercial
<p>The MRO industry requires high levels of quality to be maintained in all maintenance actions due to the risk to pilots and crew of the aircraft. These increased requirements for quality decrease the bargaining power of the aviation enterprise regardless of whether it is military or commercial. However, the MRO industry is large, and quality is enforced through the application of OEM specifications, industry standards and government regulations which mitigates the loss of consumer power (Lester &amp; Bradford, 2009).</p>	
<p>New technology trends are further changing the structure of MRO by requiring that service suppliers have the skills to keep up with these advances<sup>§§§§§§</sup>. Although the overall service provided by MRO is undifferentiated (in that it is the <i>restoration of the product back to a state where it can perform its design functions</i>), the actual MRO offering may be differentiated based new technological trends within the aviation MRO industry. For example the MRO requirements on composite material (which are common on newer aircrafts) are different from the materials used on older aircrafts. Similarly, electronic systems continue to replace mechanical systems. As electronics systems become more complex, companies will require increasingly specialised skills for aftermarket service and repair. Whilst all of these new trends may decrease the bargaining power of the aviation enterprise (military or commercial), this decrease is mitigated through OEM specifications, industry standards and government regulations which standardised the MRO input/requirements on the product.</p>	

**Table 6.8: Bargaining Power Comparison between Military and Commercial buyers**

<sup>§§§§§§</sup> Global Aerospace Market Outlook and Forecast, AIAC Phase 3 Report, (October, 2010)

[http://aiac.ca/wp-content/uploads/2015/11/AIAC-Phase-3-Report\\_FINAL.pdf](http://aiac.ca/wp-content/uploads/2015/11/AIAC-Phase-3-Report_FINAL.pdf) (Accessed in 2016)

The analyses of the buyer groups (military and commercial) according to characteristics of the market suggests that military-buyer group are concentrated, integrated, have full knowledge and a significant portion of their budgets invested in the industry which increases the bargaining power of military aviation enterprises. This is not so for the commercial buyer-group. Although a significant amount of their budget is spent on MRO services; the consumer buyer-group is not as concentrated; not integrated; the threat of backward integration is not as credible and do not have full disclosure of the MRO agencies operations and as such, they have a lower bargaining power than the military counterparts.

### 6.1.3 Threat of Substitute Products

The threat of substitute products describes those products outside the industry that have the ability to perform the same or similar function or provide the same benefit as the industry's current offerings. "Substitutes limit the potential returns of an industry by placing a ceiling on the prices firms in the industry can profitably charge" (Porter, 1980). The aviation MRO industry is closely linked to the aviation industry and continued operation of any aircraft requires (extensive) maintenance regardless of the enterprise (military or commercial). This makes the MRO an irreplaceable feature of aviation enterprises.

Nonetheless, there are growing trends within the aviation industry that indicate the threat of substitute product could in the long-term affect the competitive structure of the MRO industry. Again, these trends affect all sectors of the MRO industry.

- a) **Unmanned Aerial Vehicles (UAV).** Unmanned aerial vehicles have been applied in battlefield theatres extensively which has led to UAV's replacing manned aircraft missions. The prices of UAVs are significantly much cheaper than manned aircrafts and their operating cost are also much cheaper (Lester & Bradford, 2009). Whilst UAVs may not be as advanced to perform all the mission sets required of a manned aircraft, they are increasingly becoming substitute products which due to their relatively cheaper cost are more expendable than manned aircrafts. This could translate into significantly lower MRO input which inherently changes the competitive landscape of the MRO industry.

b) **New Technology.** The development of new technology, such as jet propulsion over propeller propulsion, can create threats of substitution within the industry. Radical improvements in operating efficiency, advanced avionics, noise reduction capabilities are some of the driving forces behind this technological drive. In 2016, an around-the-world trip was completed by a plane powered by solar energy<sup>\*\*\*\*\*</sup>. Similarly, the wider use of composites, advanced manufacturing technology requirements, and conversion to new electrical systems are also rapidly changing the way aircraft are manufactured. Airframes are now being designed with lifecycle cost considerations in mind with the desire to decrease maintenance input(s) as a key characteristic (KPMG, 2016). New lower-maintenance engineering of aircraft could present a reduction of the current high cost of maintaining legacy aircraft. While not a complete substitution to MRO, the introduction of lifecycle engineering could reduce the amount of MRO required, thereby increasing the threat of substitute products (Lester & Bradford, 2009).

There are currently no direct substitute products/services for MRO. However, the rapid evolution of technology evidenced in the popularity of UAV's and the success of newer technological advancements, the threats of substitute product while not strong now is a force that would significantly shape the MRO industry in the near future.

#### 6.1.4 Bargaining Power of Suppliers

The bargaining power of supplier is another force that can shape the competitive structure of the industry (Porter, 1980). The bargaining power of suppliers (or Supplier power) can affect the competitive environment by raising prices, lowering quality and/or reducing product (or service) availability. Similar to the *bargaining power of the buyer*, these conditions making suppliers powerful mirror those making buyers powerful. A supplier with increase bargaining power can make the competitive landscape more competitive and decrease profit potential for the buyer. On the other hand, a supplier with weaker supplier power makes the competitive landscape less competitive and increases profit potential for the buyer. Similar to the bargaining power of buyers, Porter explains that suppliers hold significant power over an industry if the suppliers are:

---

\*\*\*\*\* <https://www.solarimpulse.com/>

- Dominated by a few companies the supplier group is more concentrated than the industry it sells to.
- Not obliged to compete with other substitute products to the industry in which it sells to. For example, the competition between the suppliers of Aluminium and Steel to the same industry could affect the competitive landscape of that industry.
- The industry is not an important customer of the supplier group. If the industry is an important customer, it is very likely that the fortunes of the suppliers will be closely linked to the fortunes of the industry in which it sells to. As such, the suppliers will be inclined to protect the industry through initiatives that may include reasonable pricing.
- The supplier's product is an important input to the buyer's business. The more important the supplier's product is to the buyer, the more bargaining power the supplier has.
- The supplier group's products are differentiated or have built-up switching costs. In cases where the supplier is heavily invested in specialised ancillary equipment and processes to support the operation of the buyer, fixed switching costs are usually included in the pricing.
- The supplier group poses a credible threat of forward integration. In this case, the supplier is able to integrate the offering of its buyers into its production footprint.

Suppliers to the MRO industry provide commodity components, raw materials, logistics services and labour (Lester & Bradford, 2009). Similar to the overview presented for the *bargaining power of buyers*, this assessment explores the forces exerted on the MRO industry from industry suppliers as it applies to the main buyer-groups – Military and Commercial. Bargaining power of suppliers is similar across all MRO sectors and as such, only and over is presented as shown in

	<b>Military</b>	<b>Commercial</b>
<b>Component</b>	<p>The United States spent almost \$600 billion on defence in 2014 which equivalent to 34% of the global defence spending. However, recent trends show that the Cold War-style arms build-ups and big-ticket defence platforms that characterized the last half of the 20th century are all but gone and today's warfare is increasingly being conducted by specialised technology, computer systems, and unmanned vehicles. In this environment, it will be those that are able to display the strongest cybersecurity, IT capabilities, and R&amp;D prowess that will ultimately win (KPMG, 2016) as such, the competitive landscape is changing and the bargaining power suppliers once had is decreasing due to the shift in industry needs and focus. Similarly. Suppliers within the new military MRO focus will experience an increased bargaining power.</p>	<p>Due to the increased demand for newer aircrafts, OEMs and the supply base are under increased pressure to innovate in their models and designs in order to allow their customers (airline operators) to compete on differentiated service offerings.</p> <p>Maintaining and funding this pace of innovation, while at the same time managing the steep ramp-up in aircraft build-rates, may result in significant consolidation and new partnerships emerge in the supply base as smaller suppliers come together to achieve the scale required to meet the capital, innovation, and production levels required to compete. All of these will increase the bargaining power of the supplier.</p>
<b>Raw Material</b>	<p>Due to the specialisation required for some military MRO components, engines and airframe supplies, suppliers are unable to rapidly shift production away from military-related equipment, lowering the power of the suppliers (Lester &amp; Bradford, 2009).</p>	<p>However, with airlines diversifying their fleet composition, OEMs are increasingly starting to compete on pricing which, in turn, is putting pressure on prices and margins across the supply base which mitigates the bargaining power of the supplier.</p>

(This Table is continued on the next page.)

	<b>Military</b>	<b>Commercial</b>
<b>Logistics</b>	The role of national defence carried out by the military is effectively realised with the availability of MRO (offerings). Thus, with the offering of MRO critical to the effective performance of the military, the (i.e. national defence), suppliers will also hold increasing bargaining (Lester & Bradford, 2009).	Over the long term, the suppliers will also need to come to terms with the shift in geographical focus of OEM's (from the United States and Europe to Asia). Developing the right footprint to meet demand requirements while reducing supply chain inefficiencies will be key to success going forward (KPMG, 2016). The ability of suppliers to configure their network to support OEM's effectively will contribute to the bargaining power of the suppliers.
<b>Labour</b>	The labour forces within the military MRO structure are unionised. These unions usually experience labour shortages consequences of which affect the whole the industry (Doan, 2008). As labour shortages continue, compensation contracts between MROs and the unions require increased benefit packages, thereby cutting into potential profits and raising the bargaining power of the unions (Lester & Bradford, 2009).	The anticipated growth in aircraft production and the introduction of new technologies may result in some suppliers not having the capacity nor the capability to meet the dual pressure of increasing production rates while at the same time investing into new innovation. One way of mitigating this shortage is consolidation in the form of joint ventures and collaborations as smaller players work together to share the costs, risks, and development requirements demanded by the OEMs. Switching costs are usually included in consolidation initiatives which invariably adds to the bargaining power of the supplier.

**Table 6.9: Bargaining power of Suppliers as it applies to the main buyer group (Military and Commercial).**

### 6.1.5 Rivalry Among Existing Competitors

The final element of the structural analysis of the industry involves ‘Industry competitors’ themselves. The competitive force within this element is the rivalry among existing competitors. This rivalry refers to the threat posed to the industry (structure) by through the competition between existing firms. “*Rivalry occurs because (industry) competitors either feels the pressure or sees the opportunity to improve position*” (Porter, 1980). Whilst the competition between firms may take a form that resembles jockeying for position, it is the *intensity* of the competition itself that plays a significant role in shaping the (competitive) structure of the industry. For example, the intensity of rivalry is what influences the prices firms charge. This in turn could affect the profitability of the industry as a whole. As such, the intensity of rivalry is complementary to the ‘threat of entry’ especially with regards to understanding the profitability of the industry as a whole. Rivalry among existing competitors determines the extent to which firms are able to trade-off the value they create for their consumers among themselves which usually results in lower prices (Porter, 1980). Therefore, the intensity of rivalry plays a major role in determining the decisions made by competing firms on subjects such as price competition, product introduction and marketing campaigns.

The growth of the MRO industry closely tied to the expansion of airline capacity and utilization levels (regardless of the whether military or commercial), and with the rapid growth of the airline industry, the profitability of the MRO industry is also set for long-term growth. Thus, in an effort to remain competitive, many MRO firms have engaged practices (such as Lean) in the bid to not only mitigate operation costs but also to enhance their positioning within this competitive environment.

Conversely, with forecast<sup>+++++</sup> indicating that the average age of the global fleet is falling quickly as airlines opt to replace older aircrafts with newer, more efficient replacements; the dynamics of the rivalry between competitors also takes on a different form. This is because MRO organisations tend to focus on core competencies while outsourcing all other function. For example, the use of composite materials in airframe manufacture (as opposed to metal - Aluminium) that require fewer inspections and maintenance or the increasingly technical and

---

<sup>+++++</sup> Growth and uncertainty (KPMG, 2016)

<https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/growth-and-uncertainty.pdf>

newer avionics and next generation engines which, in turn, require more sophisticated maintenance capabilities have an effect on the competitive landscape of the MRO industry and invariably the rivalry between firms. Thus, there is an increasing move towards outsourcing within the MRO industry that allows firms to concentrate on key competencies and outsource divest non-profitable interest (Lester & Bradford, 2009).

Nonetheless, Porter (1985) suggests that the intensity of the rivalry affects the competitive environment and influences the ability of existing firms to achieve profitability. High intensity of rivalry means competitors are aggressively targeting each other's markets and aggressively pricing products. This high intensity results in a more competitive environment but a decrease in the profit potential of existing firms. On the other hand, low intensity of competitive rivalry results in a less competitive environment but with increased profit potential for existing firms. Porter suggests that the factors responsible for the intensity of the rivalry are many. These factors range from the number of competitors to the size or market share they possess. Also the rate of growth of the industry and the operating cost also help in shaping the intensity of the rivalry. For example, if the rate of growth of the industry and the operating fixed cost are high, the intensity of the rivalry will also be high. Although the MRO industry is forecasted to grow at the similar paced to the aviation industry, the MRO operating cost are relatively high thereby signally a relatively high intensity of rivalry between existing firms. Similar to the 'threat of new entrants' the following factors determine the intensity of the rivalry between existing firms.

- **Number and size of competitors:** This refers to the number and size of competitors the within the industry. The higher the number the more competitive the industry and the smaller potential for profit. Similarly, the extent of the competitor size in terms of offering and power also affects the intensity of the rivalry.
- **Fixed Costs:** This refers to the fixed cost associated with MRO operations which are generally high<sup>\*\*\*\*\*</sup>. Porter (1985) suggests that the higher the fixed cost the more the intensity of the competition. If fixed costs are high, then the intensity of the rivalry will tend to push firms to operate at full capacity so as to exploit economies of scale.

---

<sup>\*\*\*\*\*</sup> IATA (International Air Transport Association), Vision 2050 (Accessed in 2016).

- **Rate of industry growth:** This refers to the rate at which the industry grows and its potential for profit. If the rate of industry growth is low, then the intensity of the competition will be higher. As such, competing firms will seek to increase their market share to increase their profits.
- **Brand Loyalty:** Brand loyalty also plays a significant role in the competitive landscape of the industry. Whilst this may not always be relevant in all industries, the perception of the brand could enhance the competitive position of an organisation over another.
- **Production Capacity:** This refers to the availability of (production) capacity in relation to the production demand. The intensity of the competition is usually higher when there is an excess of (production) capacity resulting in rival firms seeking to exploit the economies of scale with this excess capacity.
- **Exit Barriers:** This refers to the economic, strategic, or personal factors preventing a firm from exiting the industry. For example, the ownership of specialised assets, high fixed costs could serve as barriers of exit which will result in the firms seeking to remain profitable whilst active in that industry.

Similar to the threat of new entry, other factors that affect the intensity of rivalry also include: **Switching Cost** and **Product Differentiation**. The analyses as shown in Table provide an assessment of rivalry within the aviation MRO sector. Whilst the military MRO operations are still largely carried out by authorised approved stations, the intensity of the rivalry is not dissimilar from what is experienced within the commercial sector. As such, the following analyses are provided within the context of the different MRO sectors.

	<b>Component</b>	<b>Engine</b>	<b>Line Maintenance</b>	<b>Heavy Maintenance</b>	<b>Avionics</b>	<b>Modification / Retrofit</b>
<b>Number and size of competitors</b>	<p>All MRO sectors are populated with various firms that range from MRO stations with singular focus in their offering (e.g. a landing gear repair shop) to MRO stations that have the capability to provide multiple offerings (e.g. general aircraft maintenance depot) (KPMG, 2016). However, larger MRO outfits that provide multiple offerings tend to hold more bargaining power which facilitates an unbalanced competitive landscape. Although this phenomenon is more pronounced within the Engine Sector, the unbalanced and highly populated nature of the industry as a whole lends to decrease rivalry forces amongst existing MRO organisations.</p>					
<b>Market Share</b>	<p><b>Military</b></p> <ul style="list-style-type: none"> <li>• Military MRO requirements are usually carried out by (government approved) authorised stations. Thus the market share across military MRO is limited to only a few competitors. However, with national defence departments (such as the American Department of Defence – DoD) wanting to foster competition by extending the approval to commercial MRO outfits, the intensity of the rivalry should increase. Nonetheless, with more than 70 percent of the US military airframe MRO overhaul being done by DoD air depots, the segment of airframe maintenance available for competition is small (Lester &amp; Bradford, 2009).</li> </ul>					

(This Table is continued on the next page.)

	Component	Engine	Line Maintenance	Heavy Maintenance	Avionics	Modification / Retrofit
<b>Market Share</b>	<p><b>Commercial</b></p> <ul style="list-style-type: none"> <li>Aftermarket packages provided by OEM's are increasingly becoming favourable with airline operators and as such MRO's are beginning to make significant in-roads into the MRO industry and reducing the market share between existing competitors. Conversely, the strong campaigns of OEM's in the aftermarket industry raising questions as to the level of support and priority they will continue to provide to the MRO organisation. This means that the OEM's have more bargaining power over MRO's which will be advantageous in increasing their market share. Whilst this is more pronounced within the Engine Sector, a similar trend is also being witnessed in the Component Sector. §§§§§§§§</li> </ul> <p>The lack of similarly-sized competitors decreases rivalry forces.</p>					
<b>Industry Growth</b>	<p>The growth of the MRO industry is closely tied with the growth of the airline industry (KPMG, 2016). Forecast show that global MRO spending will exceed the \$140 billion mark by 2017 - a 26 percent increase from 2014 (Srinivasan <i>et al.</i>, 2014). This rapid industry growth fosters competition and increases the intensity of the rivalry between competitors.</p>					

(This Table is continued on the next page.)

§§§§§§§§ AAR Grows In Europe As Airlines Seek PBH Support

[http://mro-network.com/opinion/2016/09/aar-grows-europe-airlines-seek-pbh-support/14831?dm\\_i=2H5E,VY4Q,63943Q,2E17A,1](http://mro-network.com/opinion/2016/09/aar-grows-europe-airlines-seek-pbh-support/14831?dm_i=2H5E,VY4Q,63943Q,2E17A,1) (Accessed in 2016)

	<b>Component</b>	<b>Engine</b>	<b>Line Maintenance</b>	<b>Heavy Maintenance</b>	<b>Avionics</b>	<b>Modification / Retrofit</b>
<b>Exit Barriers</b>	<p>Outsourcing to focus on key competencies both by the airlines and the MRO organisations suggest that the deliberate decisions were taken with regards to the area of expertise and competence. Depending upon the area of specialisation (and volume), the barrier to exit may vary. However, regardless of the sector (or customer – military or commercial) MRO investments are generally substantial (high initial capital investments in equipment and facilities) which leads towards a high barrier to exit and consequentially increased intensity of rivalry.</p>					
<b>Capacity</b>	<p>The MRO industry is characterised of both scheduled (dictated by OEM) and unscheduled (from in-service use) maintenance inputs. As such, MRO organisations tend to ‘build’ capacity to handle both requirements. As such, MRO organisations tend to have excess capacity which leads to an increase in the intensity of the rivalry as companies tend to compete for available work to utilise the (excess) capacity. Additionally, the commercial MRO work can also be seasonal as airlines tend to will tend to generate the most revenue from their aircrafts during the summer months when holiday travel is at its highest. As such the capacity held by MRO which may not be surplus to their overall production requirements is underutilised which provides the opportunity to draw additional work when not required at peak periods (Srinivasan <i>et al.</i>, 2014). Thus, the varying demand levels leads to a seasonal utilisation of capacity which increases the rivalry between competitors.</p>					

(This Table is continued on the next page.)

	<b>Component</b>	<b>Engine</b>	<b>Line Maintenance</b>	<b>Heavy Maintenance</b>	<b>Avionics</b>	<b>Modification / Retrofit</b>
<b>Switching Costs</b>	<p>The MRO industry is a low-volume; highly specialised industry and as such, switching cost are usually high. With switching cost high, the intensity of rivalry is low. However, as opposed to switching, MRO organisations are more likely to consolidate especially in areas where technologies are similar to increase their offering (operation footprint) thereby positioning themselves to increase their market share.</p> <p>Conversely, within military MRO, with only a few approved depots being able to carry out MRO inputs, switching cost is not available as there are no alternatives and this lends towards low rivalry intensity (Lester &amp; Bradford, 2009).</p>					

**Table 6.10: Porters (1985) Competitive Forces: Rivalry among existing competitors**

Porter's (1980) competitive forces help in shaping the competitive landscape of the industry. In order to remain competitive, many MRO organisations have employed practices such as Lean. As earlier established, although Lean has been widely applied resulting in significant positive outcome especially with regards to operation efficiency, Lean application does not automatically translate into enhance competitive positioning. As such, many Lean application efforts have been not been sustained (or deemed to be successful in the long-term) due to the fact that the effort applied to these Lean programmes has not been commiserate to the competitive positioning expected. As such it was crucial to understand and present the MRO competitive landscape. This understanding will help to inform the appropriation of Lean (thinking) in a way that results in better competitive positioning.

## 6.2 Achieving Sustainable Competitive Advantage through Lean

The core principles of Lean are ubiquitously evident in all sectors within the MRO. Although the suitability and benefits of Lean have been confirmed (Chapter 2), this section seeks to understand how its adoption could give competitive advantage to the adopting organisation.

The research presented so far advocates that the application of Lean usually results in achieving similar (or higher) levels of productiveness with similar (or less) resource input. Albeit a positive outcome, it is not clear what impact this has on the overall financial performance of the organisation. Research carried out into the relationship between profitability and Lean production adoption by Oliver and Hunter (1998) suggests that there are no statistical significance between high and low Lean adopters except that high level users exhibited much higher volatility in profits. Thus, Lewis (2000) carried out an empirical study to investigate the general assumption that if a firm increases its overall effectiveness in converting resource inputs into outputs (measured against criteria, including in-process and finished goods inventory, delivery and quality performance, employee numbers, floor space etc.) this lowering of relative costs should result in improved overall business performance (measured by profitability or market share etc.).

The outcome of Lewis (2000) research indicated that Lean implementation can underpin competitive advantage if the firm is able to appropriate the productivity savings it creates. The empirical study he carried out showed that the organisations with the most dramatic operational improvements (more than 40 per cent process inventory improvement) appear to have been unable to “appropriate” these savings. Although they witnessed sales growth rate of profitability (between 2-28 per cent) was not proportional to the benefits alluded to Lean realisation. Conversely, there were also other organisations that recorded remarkable increase in profitability (over 90 per cent) with much less progress along their Lean realisation routes (28 per cent in process inventory improvement). It was noted that these remarkable business performances were attributed to the ability to appropriate their Lean engagements in a way that enhances their competitive advantage. So while it is a positive outcome to record increased productivity, it is not a given that if an organisation reduces overall costs, that there will be a proportional sustainable increase in either its profitability or sales figures (investing savings to grow market share).

Furthermore, with literature review suggesting that successful Lean realisation is industry specific, it should also follow that the trajectory in developing competitive advantage via Lean adoption will also be (organisationally) specific as well. Although the principles of Lean will remain the same regardless of the context of implementation, the specificity of the actual Lean engagement as it pertains to the particular organisation could be viewed as being ambiguous and/or vague (Bartezzaghi, 1999). Literature reveals that there have been some attempts at mapping generic trajectories for what constitutes the Lean Production System. These attempts have resulted in profiles that are tedious and in some cases conflicting (Lewis, 2000). For example, Karlsson and Alstroom (1996) describe 18 different elements (each with their own sub-elements) as the bases of what constitutes the Lean production system that if successful realised, will result in positive outcomes and inherently, improve the competitive positioning of the organisation. Similarly, Oliver et al., (1996) research on a study carried out by Andersen Consulting Lean Enterprise Research in determining what comprises a Lean production system required organisations to fill in a questionnaire that typically took five-and-a-half-days of managerial time to complete. If no improvement technique is excluded, then defining what actually constitutes the Lean production process becomes extremely difficult (Lewis, 2000). Indeed one of the findings from the research presented so far suggests that “...various implementation strategies have been employed in the adoption of Lean; however, the factors responsible for its successful realisation within this industrial context remain unclear...” These points to the fact that it is important to not only explore the link between Lean outcomes and the tools/techniques that apparently delivered those outcomes but also to consider the contextual factors affecting the organisation itself. Thus, each firm will follow its own unique Lean production development trajectory which is dependent on the contextual factors affecting that organisation.

The empirical study carried out by Lewis (2000) indicated that the different starting points of each case study had a significant impact on their business performance outcomes. For example, while Case study A was driven initially by a series of investments in new technology, Case study B was driven by their Managing Director’s belief that human resources lay at the heart of any effective strategy. The demands of “leading edge” automation required the Case Study A to rely heavily on both its customers and key suppliers to provide implementation and operational expertise while Case Study B focused on reducing

its total labour costs by asking a great deal more from its staff. The strategic path taken by both organisations in achieving competitive advantage will serve as the overriding factor in determining the focus of Lean realisation. This was evident in the significant difference not only in the combinations of the tools/techniques adopted but also in the order in which they were applied. Lewis (2000) noticed that the number, duration and complexity of the Lean production initiatives varied considerably. In some cases up to 12 separate Lean principles were concurrently being applied which the staff found to be quite tedious and overwhelming. The staff surveys, he conducted indicated that while there was high levels of motivation and enthusiasm at the start of the Lean programme, the increasing number of ‘new ideas’ over the following years led to increased levels of frustration.

In summary, it is safe to infer that increased overall effectiveness achieved through Lean introduction does not guarantee a proportional increase in competitive advantage. The evidence suggests that for Lean adoption to result in notable competitive advantage, the adopting organisation need to *appropriate* the productivity savings it creates. Approaching Lean engagements with this perspective informs the resulting Lean initiatives ensuring that these efforts result in sustainable outcomes. Similarly, the contextual factors surrounding the adopting organisation also play a crucial role in shaping the Lean engagement. Whilst, the industrial-context factors (product-centric service environment) play a significant role in the Lean initiatives been adopted, evidence also suggests that the immediate organisational context play a bigger role in the development of sustainable Lean engagement programmes.

### 6.2.1 Lean and Agile Production

From the research that has been presented thus far, it is clear that Lean does not determine the orientation an organisation approach in mediating between the external drivers and its internal VDS. It only serves as a means in achieving a desired outcome. Whilst the route to competitiveness is often evident in the strategic orientation of the organisation, the role of Lean is to facilitate competitive advancement along the chosen route whatever the motivation -waste reduction and/or value enhancement. The allusion of many MRO organisations’ successes to Lean adoption (presented in Chapter 2 of this thesis) should not be confused with the orientation of the organisation. Lean is not the outcome but a means to achieving a desired outcome.

Although both literature review and the empirical study confirm Lean as a widely accepted tool in facilitating competitive advancement, there was also a significant amount of data that point towards achieving some form of *agility* (often referred to as Agile production). Hallgren and Olhager (2009) suggest that intensified competitive pressures serve as a key proponent for organisations' to achieve some form of '*agility*'. Indeed, one of the competitive routes – Best Solution which entails providing increased availability is possible with systems that have higher degree of *agility*. Also, whilst it is true that Lean focuses on reducing production cost (which in turn facilitates price competition to expand market share), literature also suggest that business environments characterised by persistently changing competitive and success factors (typical of the MRO industry) require a response that has in it a level of '*agility*' (Vokurka and Fliedner, 1998; Yusuf and Adeleye, 2002). This position is further substantiated by Vazquez-Bustelo et al., (2007) who proposed that the degree of the competition within a turbulent business environment is significantly proportional to the level of *agility* that is required in response. Other authors such as Andrew *et al* (2008) suggested that MRO organisations need to strive to achieve a level of '*agility*' in order to deal with the issues of volatility in the market.

The industrial environment has changed radically over the last two decades, with technology, market conditions and customer requirements changing at an unprecedented speed and in directions that have been difficult to foresee (Vázquez-Bustelo et al., 2007). Conversely, the intensity of competition due to globalisation is increasingly making *Flexibility* and *Innovation* key competitive priorities (Narasimhan et al., 2006). Vázquez-Bustelo et al., (2007) indicate that against this new competitive background, many firms have started re-orienting their distinctive competencies, adopting different practices and tools to improve their competitiveness (i.e. automation and flexible manufacturing systems, concurrent engineering, total quality management, strategic and cooperative outsourcing, time-based competition, business process re-engineering, benchmarking, mass customisation). Whilst some of these tools and practices are covered within the Lean approach, there is growing school of thought both within academic and industrial circles to suggest a new paradigm known as “Agile Production”. Indeed, Andrew (et al, 2009) suggests that in order to achieve the required *Flexibility* (and *Innovation*), MRO organisations need to achieve a certain level of '*agility*' which usually takes on a form that is highly responsive to customer demands, yet Lean.

Agility itself (or Agile Production), was coined as a concept by a group of researchers at Iacocca Institute, Lehigh University, in 1991, to describe the practices observed and considered as important aspects of Manufacturing (Iacocca Institute, 1991a, b; DeVor et al., 1997). Goldman (et al., 1995) described an agile system as a system that is capable of operating profitably in a competitive environment of continually and unpredictably changing customer opportunities. Similarly, Gunasekaran (1998) defined agile system as a system that is capable of surviving and prospering in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets driven by customer-designed products and services. Vázquez-Bustelo et al., (2007) defined Agile production integrates technology, human resources and organisation by creating an information and communication infrastructure, granting flexibility, speed, quality, service and efficiency and making it possible to respond deliberately, effectively and in a coordinated way to changes in the business environment. Sharifi and Zhang (2001) surmised agility as comprising of two main factors: responding to changes in proper ways and due time, and exploiting changes and taking advantage of changes as opportunities. Naylor (et al., 1999) described Agile strategies as using market knowledge and a virtual corporation to exploit profitable opportunities in volatile marketplace.

Whatever the description, there are key elements to the Agile production which can be surmised as the capability of an organisation to:

- Meet the changing market requirements;
- Maximise customer service level; and
- Minimise the cost of goods, with the objectives of being competitive in a global market and raising the chance of long-term survival and profit potential (Gunasekaran and Yusuf, 2002; Vázquez-Bustelo et al., (2007)).

All of these descriptions of an agile system lend towards the ability to be flexible which is increasingly become a key component in the way organisations seek to mediate between the external and internal drivers. To be able to respond effectively to changing customer needs in a volatile marketplace means being able to handle variety and introduce new products quickly (Hallgren and Olhager, 2009). Tsourveloudis and Valavanis (2002) regarded the main capabilities of an agile production system as the ease with which the system can change between products, and the ability to introduce new products without investments. Whilst the

volatility in MRO market is present, also as important is the unpredictability inherent in the nature of MRO operations leading to stochastic tasks and this requires that the production system is *nimble* (flexible) to meet customer demands without compromising on the other aspect of its competitive priorities – Cost, Quality and Delivery (Aitken et al., 2002).

In order to mediate between the external and internal drivers, many organisations are now employing Lean and Agile initiatives. Although several authors view Lean and Agile principles as subsets of each other (Kidd, 1994; Shah and Ward, 2003), there are some other authors that describe them as putting different emphasis on the same set of dimensions (Narasimhan et al., 2006). However, there are also a few authors that view both Lean and Agile as paradigmatically different and thus, referring to the concept of “Leagility” which seeks to combine the two (Naylor et al., 1999; Aitken et al., 2002; Bruce et al., 2004; Krishnamurthy and Yauch, 2007; Andrew et al., 2008). This is evident in the description provided by Naylor et al. (1999) which suggests that while Lean focuses on the elimination of all forms of waste, Agile makes use of market knowledge to exploit profitable opportunities in a volatile market place.

Conversely, Naylor et al. (1999) suggests that whilst Lean and Agile equally contribute towards Quality and Delivery; Lean lends more towards Cost and Agile lends more towards the Flexibility and Support (both of which are collectively described as service). Prince and Kay (2003) also made similar a distinction between Lean and Agile related priorities. They associated consistent quality, cost, and dependable deliveries with Leanness, whereas fast delivery, rapid volume change, and rapid product mix change were associated with Agility. Additionally, Narasimhan et al. (2006) conducted an empirically study into Leanness and Agility and found that Lean performers were better on Cost performance, while Agile firms performed better on quality, delivery, and flexibility. Thus, in general, good quality and delivery performance is assumed to be achievable in both Lean and Agile environments, while Cost is predominantly associated with Leanness and Flexibility with agility (Hallgren and Olhager, 2009).

With the understanding that the aviation MRO industry is a *product-centric service* industry, the application of “Leagility” to mediate the internal and external drivers becomes all the more relevant.

Interestingly, when considering the characteristics associated with Lean and Agile, there is some overlap of some characteristics that are viewed as key ingredients both Lean and Agile production systems. These characteristics include waste elimination, setup time reduction, continuous improvement, 5S and other quality improvement tools. Serendipitously, these key ingredients are consistent with the observation from the empirical study presented in chapter 4 which indicates that although there has been an increase in the adoption of Lean tools and techniques, the paradigm change required to substantiate lasting success is still lacking.

In summary, a production system can be described as Lean if it is accomplished with minimal waste while a production system is described as Agile if it efficiently changes operating states in response to uncertain and changing demands placed upon it Hallgren and Olhager (2009). However, by understanding the external factors that require an adequate response from the internal VDS, the purpose and role of Lean (or Leagility) application is increasingly becoming clearer and thus providing an appropriate sense of what is supposed to achieve.

### 6.3 Reconciling Between the ‘*External*’ Factors and the ‘*Internal*’ Value Delivery System

All external pressures solicit an adequate response by the organisations operating within such business environment. The pressure *exerted* by external factors on the MRO industry requires the industry to continually evaluate the manner in which its value delivery system (VDS) performs in order to remain profitable. However, in attempt to effectively reconcile *external* drivers with *internal* VDS, organisations actively choose their route to competitiveness (Porter, 1985) with Lean emerging as prevalent approach (Bartholomew, 2009).

The route to competitiveness is often evident in the orientation of the organisation’s management. This orientation is driven from Strategic dimension and translated across the operational and economic dimensions of the organisations’ value delivery system. The competitive strategy describes how an organization chooses to compete in a market, particularly the issue of positioning the company relative to competitors with the aim to establish a profitable and sustainable position (Hallgren and Olhager, 2009). Strategic decisions have long-term implications. They are usually captured by the core logic of the organisation which essentially represents the values and notions that form the basis for the long-term orientation of the organisation and the essence of how it intends to place itself

within the industry (Hamel, 2000). Strategic decisions tend to influence operational characteristics that an organisation should carry out internally and those that should remain external. The core logic also specifies the orientation of the organisation and its relationship to the environment (Hamel, 2000; Shafer et al., 2005). It therefore follows that the competitive route chosen by an organisation will serve as the overriding factor in determining the mode of Lean realisation.

Porter (1985) suggested that there are three major routes the *external* factors and the *internal* VDS can be mediated: Cost Leadership, Product Differentiation, and Focus. More recent studies (Redding, 2012) suggest that the mediation between external factors and internal VDS are represented as:

- **Best Price:** Processes are controlled to deliver the best total cost to the customer.
- **Best Product:** Delivering the best product in the market.
- **Best Package:** Providing the best total solution to the customer.

**Best Price:** This refers to cost-leadership strategy which comprises more emphases on cost reduction as the organisation progressively works towards achieving the status of being a low unit cost producer. This means that more attention is given to cost control in order that above-average returns even at low prices (Porter, 1980; Kotha and Orne, 1989). The attention of Lean realisation within such strategic environment will focus on cost reduction by streamlining operations to become extremely cost efficient so as to enable the organisation to offer a lower prices.

**Best Product:** This refers to a product differentiation strategy where the rationale is to avoid direct competition by differentiating the products and/or services offered usually at premium prices (Hallgren and Olhager, 2009). Product differentiation is typically expressed in the form of distinct and/or improved style or quality (Porter 1980). The objective is to create a product or service that is, or is perceived to be, unique by customers (Kotha and Orne, 1989). With the understanding that the (end) customer ultimately determines value, the focus of successful Lean realisation within this context will be to enhance this (perceived) value as opposed to cost reduction which is the focus within the Best Price orientation.

**Best Package (Solution):** The third route emphasises ‘*availability*’. The best solution is uniquely different from having the best product or the best price but an orientation where the offering to the customer is customised to meet their requirement (Santos, 2000; Ward and Duray, 2000). There is a growing trend in this type of competitive strategy as more businesses are adopting an orientation that does not necessarily offer the product itself but the ‘availability’ of what the product provides. For example, the offering is not the aircraft engine but the provision of the ‘engine power’ to fly. The focus of successful Lean realisation within this strategic orientation is improved flexibility to be able to respond quickly to customer demands. Andrew *et al.*, (2008) described this as achieving some level of *agility*\*\*\*\*\* that entails a Lean system, yet highly responsive to customer demands.

The strategic route by which an organisation chooses to reconcile the *external* factors and its internal VDS determines the competitive position of the organisation. Figure 6.2 gives an insight into the competitive position of Organisation **A** to Organisation **B**. Whilst Organisation **B** has chosen to distinct itself as a market leader in providing the best Package, Organisation **A** seems to fair relatively much better when it comes to pricing and product it offers. Whilst this is an arbitrary example, it gives an insight has to how the *external* factors could affect the *internal* orientation of the organisation and how Lean can be successfully realised within such environment.



**Figure 6.2: Competitive profiling between Company A and Company B.**

It is important to note that the **internal** and **external** aspects within the governing protocols of the **Strategic Dimension** (chapter 5.5.1) should not be confused with the *external* drivers exerted on the industry. While the internal and external aspects of the governing protocol is comprised of the Core Logic of the organisation itself, the *external* drivers comprises the market conditions in which the organisation operates.

#### 6.4 Overview of the MRO Business Environment

As global competition intensifies, it has become a necessity for MRO organisations to greater knowledge and be more conversant with better ways of maintaining competitive advantage. With Lean being herald as a means of continuously improving processes and the eliminating all non-value adding activities by reducing waste within an organization (Alabama Technology Network, 1998; Inman, 1999; Davis and Heineke, 2005; Arawati, 2011) its allure to the aviation MRO industry is no surprise. To compete successfully in today's challenging business environment, MRO organisations ought to be able to effectively integrate internal functions within a company and effectively link them to the external operations of suppliers and supply chain members. The process of producing and distributing products and services to customers is becoming the most effective and efficient way for businesses to stay successful and is central to the practice of Lean (Hallgren and Olhager, 2009).

It was identified from the literature review (Chapter 2) that direct transference of Lean from one industry to another does not translate to successful implementation. However, it was observed from the empirical study presented in Chapter 4 that the focus of Lean implementation was directed more towards the characteristics of operation closely akin to manufacture than its service counterparts. Whilst the benefits of Lean were still being seen albeit the one-sided focus of implementation, it became necessary to fully explore the MRO context of application so as to facilitate successful Lean realisation within this new environment. Since the MRO business environment is described as being a product-centric service one, a better understanding of this field of application will only help to enhance successful Lean realisation. This chapter thus focused on the MRO business environment by considering key aspect of the MRO business model. A comprehensive framework to precisely describe and quantify aviation MRO business models was developed (Mason and Morrison, 2008), based on both literature review and leveraging on the empirical study presented in Chapter 4.

The framework comprised mainly of the value delivery system of the MRO industry and considered the various dimensions to this system. The various dimensions were referred to as the governing protocols within which Lean will be realised. They consist of the Strategic Dimension, the Economic Dimension and the Operational Dimension. Within each dimension are key business decision areas which Lean will seek to directly influence to eliminate waste, enhance value and inherently improve the competitive position of the organisation. The framework represents the architectural backbone of the MRO value delivery system.

In order to cope with increasing competitive intensity, there is a propensity for MRO organisations to improve their efficiencies by addressing specific needs in isolation. However, without a full grasp of the different aspects to the MRO value delivery system, there is a susceptibility that the outcome of such initiatives are solutions to specific problems rather than stepping-stones in an intended direction (Hayes and Pisano, 1994). The focus of this research however is to enhance competitive advantage through successful Lean realisation and thus, applying Lean tools and techniques in isolation to address specific needs may not necessarily serve as a stepping stone in achieving overall competitive advantage. The first step is first to understand the context of Lean application and then understand how Lean is to be expressed within this context so as to achieve the intended goal. This chapter

thus sought to elucidate on the business environment through understanding the system through which value is delivered. It is upon this understanding that Lean can be more accurately applied to eliminate waste and to enhance value. Furthermore, Lean can then be more correctly appropriated to address the gap between market conditions and current status to enhance competitive advantage in a sustainable manner (Narasimhan et al., 2006).

## 6.5 Strategic Response: Dominant Means of Mediation and associated Success Factors

The competitive strategy which an organisation chooses is indicative of its response to the forces (external and internal drivers) being exerted on it. Within the aviation MRO industry, competitive strategies can be varied to deliver the Best Product, Best Price, or Best Package/Solution. The Moderating factors for the successful Lean realisation are constrained by the strategic decision(s) of the organisation. They serve as the singular most significant influence on the direction of the Lean success. For example, the intensity of the global competition (external driver) could result in an organisation seeking to adopt a Best Price strategy (internal response), which could focus Lean realisation efforts around a cost leadership approach. Thus, “competitive strategy” is modelled as having a possible mediating effect on the choice of improvement programme which will be assessed within the metrics of *cost*, *quality*, *delivery*, *flexibility* and *innovation*. This section investigates the dominant means of mediation and the associated success factors.

### 6.5.1 Means of Mediation – Cost Leadership

A key strategy in mediating between the external and internal drivers posited by Porter (1997) is the *Cost Leadership* strategy. An organisation adopting a *cost leadership* strategy seeks to perform its operation at the lowest production cost, which returns a cost advantage over its competitors (Stahl and Grigsby, 1997; Miltenburg, 2005). Cost leadership strategy is often facilitated by initiatives such as the urgent drive to achieve efficiency in all operations, leveraging on the economies of scale, size, scope and cumulative experience (learning curve).

It is important to note that *Cost Leadership* is different from *Price Leadership*. An organisation with the lowest cost producer (*Cost Leadership*) may choose not to offer that lowest price (*Price leadership*) to the customer. The adoption of a *Cost Leadership* strategy is one way of mediating between *external* and *internal* drivers which translate into having a

having a low cost structure and thus, allowing the organisation to be more effective in price competition whilst remaining profitable (Stahl and Grigsby, 1997).

While the *cost leadership* strategy can be highly successful; it can also be difficult to realise. This is because in the bid to increase profit, an organisation can either choose to be content with its current market share and use its low cost advantage to earn a higher profit margin on each unit sold or it can use its low cost advantage to under-price competitors and attract price sensitive buyers in greater numbers (Miltenburg, 2005). Nonetheless, this strategy has been widely employed within the aviation industry which is typically known for very thin profit margins if high ticket prices are not charged. However, airlines like Southwest Airlines (and indeed many low cost carriers) have adopted the cost leadership strategy to great profits by positioning themselves as cost leaders. Southwest attempts to offer the lowest prices possible by being more efficient than traditional airlines. They minimize the time that their planes spend on the tarmac in order to keep them flying and to keep profits up. They also offer little in the way of additional thrills to customers, but pass the cost savings on to them<sup>††††††††</sup>.

With initiatives that are akin to Lean ideals, this Lean approach is often regarded as a dominant means in successfully realising a Cost Leadership strategy. Naylor et al. (1999) described Lean as developing a “...*value stream to eliminate all waste...that makes high-capacity utilization possible thus leading to lower manufacturing costs. Lean manufacturing in this sense is a program aimed mainly at increasing the efficiency of operations.*” This position is further substantiated by Hallgren and Olhager (2009) whose empirical study revealed the Lean approach as the most dominant and effective way of successfully realising the cost Leadership strategy. Furthermore, the literature review presented in chapter 2 of this thesis also alluded to a significant increase in the adoption of Lean ideals in mediating the global economic crises of 2008. For example, the Landing Gear product division of Lufthansa Technik, launched a global initiative of becoming the lowest-unit producer within the industry sector. This competitive priority led to an increased emphasis on Lean implementation across all its sites and “...*this emphasis on Lean to facilitate the cost leadership strategy contributed to its survival through the global economic downturn*” Jonathan Rumble (Sale Director, Lufthansa Technik Landing Gear Services, UK).

---

<sup>††††††††</sup> <http://smallbusiness.chron.com/examples-cost-leadership-strategy-marketing-12259.html> (accessed 9th of April, 2015)

Miltenburg, (2005) posits that a cost leadership strategy is suitable when the product/service is readily available from many companies and there are few ways of achieving differentiation. These features are consistent with the aviation MRO industry especially as the differentiation in the basic service offered (re-manufacturing) is difficult as these operations are typically specified by the Original Equipment Manufacturers (OEM) with very little room for deviation. Differentiation within the aviation MRO industry is generally within the realms of the total package/after-sales package offered. Other prevalent features that make cost leadership attractive include market conditions where price competition is intense and customers have significant power to bargain prices with low switching cost in changing from one supplier to another. All of these features are typical of the MRO market especially with the increased globalisation where there is an increase in the number of MRO start-ups in countries with relatively lower labour cost. The ubiquitous allusion by MRO organisations to the adoption of Lean (as presented in chapters 2 and 4 via the literature review and the empirical research conducted respectively) is therefore no surprise.

It is important to recall that the achievement of ‘Leanness’ in a best-in-class company is largely realised within the operational dimension – particularly within the framework of key characteristics of operation (Chapter 5). The influence of Lean within the characteristic of operation framework will be observable and as such, enable an assessment of the extent of Leanness and inherently, the success of its cost leadership strategy. The following sections elucidate on the success factors required within the cost leadership strategy in mediating between the external and internal drivers.

<b>Structural characteristics</b>	<b>Infra-structural characteristics</b>
Process and Technology	Human Resources
Capacity	Quality control
Facility	New Product/Service Range and introduction
Supply Chain Positioning	Performance measurement
Planning and Control	Supplier Relations
	Customer Relations

**Table 6.11: Key Characteristics of Operation Baines et al. (2009)**

### 6.5.2 Cost Leadership Strategy Success Factor: Cost of Production Inputs

The cost of producing good and/or service is linked to what the organisation pays for key resource inputs. Production costs are largely grouped into *direct* (variable – depending on volume) and *indirect* (fixed – does not depend on volume) cost. Direct costs usually include the cost of the raw material and the labour involved in producing the product (product – good and/or service). Indirect costs usually include the overhead cost such as rent, salaries or utility expense etc. Empirical research carried out by Liker and Choi (2004) revealed that of the 100 biggest U.S. manufacturers, 48 cents out of every dollar of sales in 2002 was used to buy materials. This not only shows the vast nature of the cost of production inputs but also provide an opportunity where savings can be made to enhance competitive advantage. Reducing the cost of all the key inputs of production will significantly contribute towards successfully realising a cost leadership strategy. The ideal of Lean is to eliminate all forms of waste which is akin to reducing the cost of production inputs to achieve cost leadership status. Although Lean will seek to engage all aspect of the value delivering system in eliminating waste, there are particular areas that directly affect cost of Production inputs both within the structural and infrastructural characteristics of operation of the MRO value system.

Although these characteristics are identified as the dominant business decision areas within which the cost of production inputs can be influenced, it is worth noting that it is not limited to these characteristics alone. Furthermore, changes within these characteristics of operation may have secondary impacts in other characteristics of operation. Where these impacts are considered to be significant will be highlighted and elucidated on.

The Facility characteristic of operation typically deals with the choice of production sites, their location and specialisation (Hayes and Wheelwright, 1984). This characteristic of operation also influences the *Human Resources*, skills, information and possibly finance that are available to the organisation. Cost leaders tend to seek regions that offer the best balance in cheap production cost such as low energy cost but with the availability of skilled labour at lower rate. Historically, MRO organisations have sought to locate themselves in regions that gave strategic advantage especially in terms of proximity to customer. However, the effect of globalisation has meant that locating the organisation close to the customer no longer serve as the order winning criterion especially because the customer has global list of suppliers with the

ability to bargain prices at low switching cost from one supplier to another. There is also a growing need to have the support close to the product (aircraft) and not the customer itself. Global MRO support is increasingly becoming a necessity for airline operators; the need to adapt to this evolving demand is becoming a necessity for survival and competitiveness. Current industry practice is that the global support required by the airline operators is still being expedited from locations far away from the product (aircraft) and the suppliers. Problem troubleshooting and resolution from distant locations do not always translate into a reduction in production cost neither does it support the effective and quick response to changes in the information from the market (Goldman et al., 1995).

Whilst the adoption of Lean may not be able to change the location of the organisation neither does it advocate for the set-up of satellite sites at all customer locations across the globe, Lean principles such as *keiretsu* can be applied to mitigate this issue. *Keiretsu* refers to a close-knit network of vendors that continuously learn, improve, and prosper along with their parent companies. Best-in-class Lean organisations such as Toyota have historically employed this approach to reduce production cost whilst maintaining quality. They were able to achieve this by reducing the number of suppliers they did business with and awarded the remaining customers with long-term contracts. They also encouraged top-tier vendors to manage the lower tier vendors and ensured that the top-tier suppliers produced subsystems instead of components, to take responsibility for Quality and Production costs which subsequently contributed to a better just-in-time (JIT) delivery rate (Liker and Choi 2004). This allows the facility to still remain in its location but strategically partner with global vendors who are closer to the *product* from which the customer support can be more quickly expedited. Re-evaluating the organisation's supply chain Positioning helps to ensure that the organisation is focusing on its strengths by exploiting the opportunities that exist in the human resource closest to the product. Other organisations have made significant upgrades within the Process and Technology characteristics of operation particularly within the Engine sector and have developed schemes that mitigate the proximity issue by developing programmes which provide real time information about the *product* and subsequently, the ability to rapidly reconfigure the production process to meet both customer and internal production demands. An example of such a programme is an 'Integrated Vehicle Health Management' (IVHM) system which is used by Rolls Royce to great success. Although these initiatives take time to implement and realise, trends in the global market suggest that they will become necessity rather than an option for competitive advantage.

Competitive priorities and performance measure also suggest that the application of Lean within these characteristics of operation also suggest better performance in terms of Flexibility, Delivery and Innovation. The adoption of Lean tools such as *keiretsu* and programmes such as IVHM allow for more flexibility in configuring operations to meet customer request. Empirical evidence within the manufacturing industry suggests that organisations that have successfully achieved *keiretsu* are able to reduce production cost by up to a quarter (25 percent). Indeed While U.S. automakers take two to three years to design new cars, organisations that have successfully implemented *keiretsu* (such as Toyota and Honda) were able to consistently deliver new cars in just 12 to 18 months with a J.D. Power and Associates rating them to better than their counterparts in promoting innovation (Liker and Choi, 2004). Thus, the application of Lean to address the cost of production inputs suggests a positive outcome in all the key competitive performance measure (cost, quality, delivery, innovation and flexibility) which suggest enhanced competitive advantage.

### 6.5.3 Cost Leadership Strategy Success Factor: Economies of scale

It is the general understanding especially within the manufacturing context that in order to pursue a Cost Leadership strategy, it is advantageous to perform operations over larger volumes. This will facilitate the spreading of the production cost resulting in cost per unit enabling a cost leadership strategy. The process of spreading the cost is over large volume is regarded as the *economies of scale* in production. *Economies of scale* refer to economic efficiencies that result from carrying out a process on a larger scale<sup>\*\*\*\*\*</sup>. These economies of scale come about because indirect (fixed) costs, such as plant, property, equipment and overhead, can be spread across the overall output. For example, certain overhaul operations will have machining operations that require the purchase of machinery and associated overhaul equipment. The set-up will be the same whether the volume of overhaul products is small or large, however, the larger the volume the lower the unit cost of each product. With the MRO industry being a product-centric service industry, employing the economies of scale present an opportunity that can be crucial is successfully realising a cost leadership strategy.

---

\*\*\*\*\* <http://smallbusiness.chron.com/economies-scale-service-industry-81253.html> (accessed April, 2015)

A principle best-in-class Lean organisations have employed in realising economies of scale is Work Standardisation. Whilst economies of scale is often associated with mass production, work standardisation allows for easy replication and thus provide the organisation with the opportunity to be able to improve efficiency and increase flexibility to be able to produce more in the same amount of time when required (Cusumano, 1985). Deconstructing the work into smaller and simpler steps and standardising these work packages allows the organisation to improve its operation efficiency which significantly ensures easy replication and allows for JIT whilst maintaining Quality. This approach is ubiquitous within MRO organisation. Firstly, OEMs tend to specify in their overhauling instructions the procedure and process that the MRO organisation have to adhere to in carrying out the overhaul input on the product. By specifying the overhauling procedure and processes, MRO organisations can organise and standardise their operations. It also means that MRO organisations can arrange the layout of their facility to be consistent with their standardisation and enable ease of replication. There are generally three ways of organisation a shopfloor layout –Functional, Production line or Cellular layout.

In the **Functional layout**, tend to organise their machinery and equipment by technology. For example, the machines with similar capabilities are located close to each other e.g. grinding machines are located close to each other such that all grinding requirements are carried out in the same area of the facility. This makes the Functional layout easy to construct and flexible. It also makes it easy to increase capacity and makes it less vulnerable to interruptions. However, the Functional layout also fosters large WIP (Work in Progress) which could lead to lower efficiency arising from multiple schedule points and long lead times involved (Heinävaara, 2010). This is because Functional layouts are typically driven by machine use effectiveness which usually translates into in (large) batches and WIP. This approach is not entirely consistent with Lean ideals as batching is seen as not supporting continuous flow and visual management especially as quality defects take much longer to be detected in batching systems. However, with MRO organisation dealing with more than more product type, the Functional layout still offers advantage in that all similar operations albeit different product types can be carried out at the same location with savings in the machine set-up times.

The **Production Line** layout although quite common within the automotive industry is also gaining popularity within the Engine sector of the MRO industry where a singular product (or very similar products) is/are produced on the same line. This layout allows for the production

process to be paced (takt) and provides more visual management controls and as such, the factual yield of the production line is more easily calculated in advance. Although WIP is minimized from the continuous flow, the stochastic nature of MRO repair operations suggest that the Production line are more suited to aspects of the overhaul that are standardised e.g. disassembly and assembly operations. The operations such as machining, plating, test may not be ideal in MRO operations as they tend to be stochastic with the possibility of having little iteration between sections. A disadvantage of the Production Line layout apart from being quite expensive to set up is that it is quite difficult to increase capacity and any disruption in the production could potentially halt the entire production.

**Cellular manufacturing** combines both aspects of the Functional and Production Line systems. It comprises organising the layout to have cells that are responsible for series of tasks e.g. a sub-assembly unit. Employees are often organized into multi-skilled teams with a single point of control for each cell making the workforce more motivated and easier to manage (Heinävaara, 2010). Although the Cellular system offers the flexibility of incorporate many operations and the installation of the necessary machinery to carry out these operations, capacity utilization rate can still fluctuate which could result in longer work cycles especially in comparison to the Production Line system.

Whatever the layout adopted by the MRO organisation, these are some of the ways by which Lean thinking can be employed in harnessing the benefits of economies of scale within the MRO business environment.

Advancement in Technology also helps to provide MRO organisations with several avenues to improve efficiency and create economies of scale. The Internet, for example, allows businesses to reach millions of potential customers around the clock, take orders, and even collect pre-qualifying information with minimal input from employees. Software packages run the gamut from basic accounting to enterprise resource planning and human resources management to even real-time data analyses of the technical performance of the product, all of which reduce the total workforce needed to achieve the same results. This is consistent with the notion that similar activities are carried out on a larger scale with smaller production cost(s). For businesses that operate in the field, fleet tracking systems for a host of different aircrafts and customers improve routing and reduce costs using technology to leverage on the economies of scale and contributing directing to the Cost Leadership strategy.

It was observed from literature that Lean companies do have a related benefit that comes from size. While not truly an economy of scale, large companies have greater resources and can develop capabilities, systems, and infrastructure that support Lean efforts. A big organization can dedicate space to a continuous improvement / kaizen room and workshop stocked with tools and materials. They can create a cadre of internal talent that can teach others and share best practices. They can hire automation experts and tooling experts who can quickly build *hanedashi*<sup>§§§§§§§§§§</sup> devices (auto ejectors) and production fixtures. The costs of those capabilities are allocated across a larger organization, so become feasible.<sup>\*\*\*\*\*</sup>

In smaller organisations, it is not unusual for businesses to often achieve internal economies of scale by outsourcing specialised tasks and processes to external organisations. For example, activities such as payroll and data-centres can be outsourced such as to facilitate lower unit cost production within the company. This practice is also quite common within subsidiaries (or non-competing) entities of a larger business organisation. For example, within the Lufthansa group, certain data-processing, payroll duties, annual tax, purchasing and even some sales functions are processed by a central unit which reduces the unit cost of the local business entity and thus leveraging on technology and size to achieve economies of scale.

#### 6.6 Means of Mediation: Product (or 'Offering') Differentiation

Another way through which organisations seek to enhance competitive advantage is through product differentiation. This is achieved by making a product more attractive, contrasting its (unique) features with other competing products thus creating a superiority impression which is valued by some customers. The focus (and/or the emphasis) of successful Lean realisation within this context will thus be different from a Cost Leadership strategy. However, since the MRO industry is not responsible for original manufacture but he re-instating of design features, the key emphasis within this context is 'Quality'. As expressed in earlier section of this chapter, rapid changes in the economy suggest that producing more – however efficiently – is not necessarily better (Fornell et al., 1996). It is increasingly becoming necessary that in

---

<sup>§§§§§§§§§§</sup> Hanedashi - Automatic unload of the work piece from one operation or process, providing the proper state for the next work piece to be loaded essential for creating flow and eliminating waste.

<http://www.simplertraining.co.uk/hanedashi-definition.html>

<sup>\*\*\*\*\*</sup> <http://www.velaction.com/economy-of-scale/> accessed 2014

order to compete successfully within modern economy, organisations must have quality beyond the competition.

Prevalent within Lean literature in addressing Quality is an approach referred to as Total Quality Management (TQM). Total quality management (TQM) as a management strategy aims to enhance customer satisfaction and organisational performance through providing high-quality products and services through the participation and collaboration of all stakeholders, teamwork, customer-driven quality and continuously improving the performance of inputs and processes by applying quality management techniques and tools (Mosadeghrad , 2014). Dahlgard and Dahlgard-Park, (2006) describe Total Quality Management as “...a company culture characterized by increased customer satisfaction through continuous improvements, in which all employees actively participate...” Consistent with successful Lean realisation, a successful TQM implementation is related to economic and performance success. The benefits and improvements are observable within areas of fewer defects and errors, reduced waste, increased sale, increased productivity, increased profit and market share, stronger relationships with suppliers and increased employee and customer satisfaction (Brah et al., 2002; Hansson and Eriksson, 2002; Hendricks and Singhal, 2001; Kaynak, 2003; Mosadeghrad , (2014).

However, it is important to note that although TQM is a subset of Lean, it is observable from literature that its realisation is more akin to the Agile approach. Empirical studies have shown the Agile approach to exhibit stronger relevance with the differentiation strategy (Hallgren and Olhager, 2009). Whilst a cost-leadership strategy is well aligned with the Lean approach, Hallgren and Olhager (2009) posit that the differentiation strategy is more aligned with Agile approach. The competitive intensity of the market and the rapidness of change highlight *quality* and *flexibility* as dominant performance measures, requiring a response that is more aligned with the Agile approach. This is because the Agile approach tends to provide better fit as an improvement initiative in realising significant positive impact on *flexibility* in addition to similar positive impacts on *delivery* and *quality* performance. Although there is no significant positive impact on *cost* performance, Agile performers have developed capabilities that emphasize *flexibility* but also *delivery* speed and reliability as well as *quality* conformance - capabilities that are more useful in a product differentiation strategy.

## 6.7 Means of Mediation: Best Solution

There is a growing paradigm shift within the aviation industry which is moving towards servitized business models. These servitized business models use services as a basis for competitive strategy (Baines et al., 2007). This was warranted more flexibility and innovation from the MRO industry in order to adequately deal with customer demands that change quite rapidly (Wise and Baumgartner, 1999). Again, the growing popularity of these support packages required by the customer will serve as the overriding factor in determining the mode of Lean realisation. However, literature review reveals that the flexibility and innovation required in achieving competitive advantage within this strategic response is a degree of *agility*. This is because key characteristic associated with the agile approach is that it is highly capable of developing new products and providing customisation opportunities in an efficient manner (Hallgren and Olhager, 2009). The following section thus explores, the study into the adoption of Lean can be extended beyond the typical MRO facility to also include its adoption in MRO-type *operations* within the aviation industry. However, the study presented in this thesis was focused on the adoption of Lean within typical aviation MRO facilities.

## 6.8 Competitive Priorities and Performance Measurement

In seeking to understand how Lean can be successfully realised within MRO context, this research has elucidated on the MRO value delivery system (VDS); the external forces within its competitive environment; and the typical mediation between the *external* factors and the *internal* VDS. However, in order to know how successful this mediation is, this section seeks to explore the key metrics that are useful in assessing the performance of Lean realisation whatever the orientation of the mediation. Assessing the performance is important because as succinctly described by Royal Society of Arts, Manufacturers and Commerce (RSA): *to achieve sustainable business success in the demanding world marketplace, a company must ... use relevant performance measures* (RSA, 1994; Neely, 1999). The expectation is that the mediation route adopted by the organisation will be evident in operational performance. Thus, in assessing the success of Lean within this context, the appropriate measures are to be applied whatever the orientation employed in mediating between the external and internal drivers.

Bhasin (2008) explains that having a good understanding of the performance measures helps to provide a better indication of the amount of *resource* that is to be allocated internally to meet varying external demand (Neely, 1999; Neely et al., 2005; Womack and Jones, 2005). This suggests that using appropriate indicators not only help in ascertaining the organisation's competitive status but contribute towards the effectiveness of the converting (firm) resources into customer value Fawcett (et al., 1997). It is not unusual to witness organisations using generic measures with little consideration of their relevance. There is a danger that using inappropriate measure could be counter-productive as it could encourage the wrong type of behaviour. However, whilst some metrics may be more relevant at certain times, it is important to note that an accurate description of the organisations profile can only be achieved when all the appropriate measures are equally considered (Bhasin, 2008). This is because in isolation, an internal measure may intimate that a company is performing well whilst the external measures depict poor performance. For example, reducing the defect rates may be in line with internal strategy, yet the company could be viewed negatively by the market resulting in a deterioration of its share price (Bhasin, 2008). Thus, the challenge is to choose the right measures for the appropriate level of the organisation (Booth, 1996).

Literature suggests that the main performance measures typically adopted are within the following five distinct areas:

- Cost;
- Quality;
- Delivery;
- Flexibility and
- Innovation.

Contained within these distinct performance measurement areas are other practice bundles. For example, within the Quality performance measures are multiple dimensions described by Garvin (1987) – 8 quality performance dimensions although '*conformance to specifications*' is regarded as a key Quality parameter that is more commonly used (Hill and Hill, 2009). Fawcett (et al., 1997) suggest that these distinct performance measures cut across both the traditional manufacturing and traditional service industries alike. Within the manufacturing sector, they suggest that there are five competitive priorities - Cost, Quality, Flexibility, Delivery and innovation as the drivers for manufacturing success. Likewise, within the

Service industry, there are three primary competitive dimensions - Cost; Customer Service and Innovation. However, within Customer Service dimension they indicate that several organisations distil this measure into three distinct dimensions which are: Quality, Delivery, and Flexibility. Conversely, it is safe to adopt a similar approach to a product-centric service environment which seeks to espouse element from both the Manufacturing and Service industries and meaning that these five competitive performance measures will be present in the aviation MRO industry.

The main objective of this section is not to delve into the details of each distinct performance measure but to use these measures as a guide in understanding the impact it plays not only in assessing the organisations' competitive status but also, the influence it plays in the organisations' strategic decision making. This is because, an organisation's choice of competitive priorities should influence decision making in the resources that are developed and organized to achieve selected goals in a way that leads to superior performance in areas of strategic emphasis . Thus, in order to effectively balance the internal and external pressures, the strategy direction of the organisation and the performance measurement must be aligned so that they both promote desired improvements in operational performance (Fawcett et al., 1997).

#### 6.9 Relevance of Performance Measures to Lean Realisation

It is important to know how key performance measures can guide and drive an organisation's operations towards superior results in any area (Bhasin, 2008). For example, whilst benchmarking and best practices can yield positive results, if not careful, this could also lead in the wrong direction by focusing on the same processes and practices of the industry, without paying sufficient emphasis on the customer (Malone and Sinnett, 2005). With literature suggesting that Lean is able to deliver a host of benefits that are vital in enhancing the competitive position of the organisation, appropriate measures are to be adopted which are effective in confirming these achievements. To build a sustainable Lean foundation that consistently yields dramatic company-wide improvements necessitates a roadmap which includes choosing the appropriate performance measures that enable the organisation to gauge whether progress is being made against goals and targets.

Within the five distinct areas of performance measurement, an approach of assessing the success of Lean realisation is by using a “Balanced Scorecard”. Kaplan and Norton (1992) proposed the balanced scorecard (BSC), as a means to evaluate corporate performance from four different perspectives: the financial; the internal business process; the customer; and the learning and growth. Their BSC is designed to complement “financial measures of past performance with their measures of the drivers of future performance”. The name of this approach is reflected in the intent to keep score of a set of items that maintain a balance “between short term and long term objectives, between financial and non-financial measures, between lagging and leading indicators, and between internal and external performance perspectives” (Bhagwata and Sharmab, 2007).

Whilst the scorecard is customisable to suit the organisation it does serve as an Lean integrated way of assessing the organisation’s performance against what Lean is required to deliver. The promised benefits of Lean can be easily tracked using this measure e.g. shorter lead time, greater flexibility, lower inventory, better customer service and higher revenues. It also provides a means of tracking the organisation's intangible and intellectual assets (Kaplan and Norton, 1992) such as the quality of the products and services; motivation and skill of the employees; the responsiveness and robustness of internal processes alongside satisfied and loyal customers.

<b>The four Parameters in a Balanced Score Card (Kaplan &amp; Norton, 1992)</b>	
Customer Perspective (Value adding view)	Financial Perspective (Shareholders’ view)
Mission: to achieve our vision by delivering value to the customer	Mission: to succeed financially by delivering value to our shareholders
Internal Perspective (Process-based view)	Learning and growth perspective (future view)
Mission: to promote efficiency and effectiveness in our business processes	Mission: to achieve our vision by sustaining innovation and change capabilities through continuous improvement and preparations for future challenges.

**Table 6.12: Sample Balance Score Card (BSC)**

Other approaches that can be used in assessing the success of Lean realisation include the Dynamic Multi-dimensional Performance (DMP) framework (Maltz et al., 2003). The approach aims to capture success as a dynamic, on-going concept that is judged on various timeframes inclusive of multiple stakeholders. The DMP framework has various characteristics which taken together distinguish it from other frameworks and addresses certain limitations of previous models. The DMP framework seeks to assess performance along the lines of 5 distinct areas: Financial, Process, Market, Customer and Future. These distinct areas give the DMP framework a certain level of comprehensiveness which may not be readily obvious in previous approaches.

The “Customer” dimension addresses the needs and perception of the external customer; the “Process” dimension concentrates on the internal dynamic management; “People (development)” recognises the critical role of the firm's employees and the “Future” dimension is focused on preparing for change whilst sustaining the organisation's vitality for years to come. Furthermore, the DMP framework provides an opportunity to examine an organisation's performance in multiple time horizons, i.e. the “Financial” represents the very short-term, whereas the “Future” looks at the very long-term. The “People” dimension explicitly acknowledges the critical roles of multiple stakeholders and addresses a major limitation of the balanced scorecard. Equally, the DMP framework depicts sufficient flexibility to be used by different organisations in different industries (Bhasin, 2008).

It is important to note that whilst no single performance indicator can capture the complexity of an organisation (Arora, 2002), in order to fully integrate Lean philosophy in performance measurement the main consideration should be centred on ‘value’ (Shah and Ward, 2003; Womack and Jones, 2003). However the following areas remain key categories that should be used in line with Lean assessment: Financial, Customer led indices, Process, People and parameters that look into the organisation's future.

### 6.10 Chapter Summary

The study presented in the chapter confirms that the successful introduction of Lean does not automatically translate into improved financial performance. Although Lean introduction will result in positive outcomes, these outcomes of themselves does always result in enhanced

competitive advantage. The organisation's ability to appropriate the value generated through Lean adoption is what results in the competitive advantage. This is because the benefits generated by the Lean is not correctly appropriated could be flowing from the adopting organisation into the hands of the other dominant key players. For example, in the aviation industry where OEMs are beginning to compete on services, the value generated through Lean introduction in smaller MRO organisations may not result in improved financial performance or market positioning

Furthermore, it was noted that the overriding factor in determining the mode of Lean realisation are the contextual factors affecting the organisation. These contextual factors extend from the factors associated with the context of application to also include the immediate contextual factors affecting the adopting organisation. For example, the contextual factors affecting the MRO industry are factors that relate to product-centric service environment, while the factors that relate to the adopting organisation include the starting position of the organisations Lean journey. For example, the starting point of an organisation's Lean journey might be heavily influenced by skill level whilst others might be technologically driven. Hence, why there cannot be a direct transference from one industry to another, and indeed, one organisation to another.

Therefore, it became increasingly clear that the overriding factor in determining the mode of Lean realisation are the strategic route chosen by the organisation in mediating between the external factors and the internal value delivery system. The external drivers are typified by the existence of high-competitive pressure which necessitates an equal and adequate response from the industry. Three distinct options were identified: Best Product, Best Price and Best Solution. The Best Product route is more closely associated with Best quality, product features or service. However, since the MRO industry does not manufacture the product and mainly provides a service, it is not in a position to provide better product features. Conversely, quality within the aviation industry is not viewed as order-winning criteria but more as a market qualifier, it is not usually a typical response in mediating external pressures. The typical responses to these external factors within the aviation MRO industry are Cost leadership (associated with Best Price) and Best Solution. The competitive strategy as an internal factor drives the choice of Lean and Agile approach, and has a mediating effect on the relationship between the competitive intensity of the industry and operations capabilities. A cost-leadership strategy fully mediates the choice of Lean approach whilst an Agile

approach is more akin with Best solution Strategy. Although the core principles of Lean will remain the same regardless of the mediating route chosen, its expression will be different within them. Based on this understanding, caution should be taken in tool/techniques adopted as empirical evidence shows that applying too many tools/techniques and not in the ‘right’ manner could be overwhelming and tedious. However, it has become increasingly clear that contingency and complexity are the dominant characteristics of any successful implementation process (Lewis, 2000).

Also, as described in earlier sections of this chapter, there are five distinct competitive priorities – Cost, Quality, Delivery, Flexibility and Innovation. The strategy by which an organisation chooses to respond to each of these competitive priorities is different and these decisions will have notable impact on the value delivery system. The strategy in seeking to achieve cost leadership will be different from the strategy in seeking to achieve more flexibility. Thus, it is safe to deduce that the moderating factors pertinent to a strategic route may be different to another. It thus becomes increasingly clear that there is no one universal approach in mediating between the internal and external drivers that is applicable to all (Henderson and Larco, 2003; Ransom, 2008).

In order to cope with increasing competitive intensity, many organisations attempt to improve their operations by addressing only specific needs without the full understanding of how their actions in one dimension affects the overall business performance. Depending on their analysis of the requirements of the marketplace, they are likely to choose different paths of improvement (Hallgren and Olhager, 2009). These improvement parts are usually a bundle of practices which are implemented in specific dimensions of the business with primary and secondary effects in other aspects of the business. Different improvement programmes cultivate different capabilities over time and it is important that the content, process and impact of these programmes are clear. It is important therefore to understand the different response routes by which organisations seek to mediate between the internal and external drivers on their business. This understanding will equip the organisation with the ability to be able to more accurately decide what measures to take and when to take them with the buoyancy of predictable outcomes. The response route through which an organisation mediates between the internal and external drivers is usually represented by the Strategic decision of the organisation. The bundles of practices that arise from the strategic decision are usually implemented within the Operational dimension with the aims of establishing a

profitable and sustainable position. This chapter completely satisfies objective 3 of this research

## 7. CASE STUDY OPERATIONALISING THE APPLICATION OF LEAN WITHIN THE MRO VALUE DELIVERY SYSTEM (VDS)

The aim of the research has been to understand and establish successful Lean realisation in MRO context to enhance competitive advantage. In realising this aim, this research has first sought to understand the status of MRO Lean engagement from literature (chapter 2) and through an empirical study (Chapter 4). It was observed from the synthesis of results from Literature review and empirical study that although there was positive engagement of Lean, it remained unclear as to how Lean can be appropriated to facilitate competitive advantage. As such, the means to achieve this competitive advantage - the MRO value delivery system (VDS) was first established presented (Chapter 5) and then factors responsible for competitiveness within the aviation MRO was established (Chapter 6). This chapter seeks to operationalise the delineated VDS based on the understanding of competitiveness as it applies to the MRO via a case exemplar. The chapter describes the final phase of this research programme which aims at validating the approach to Lean application within the aviation MRO industry that enhances competitive advantage.

Thus, presented in this chapter is first the protocol for validation (Section 7.1). The assessment criteria used for this study are *feasibility usability* and *utility*. The *feasibility* and *usability* parameters were evaluated using semi-structured interviews (Sections 7.2 through to 7.4). However, the evaluation *utility* parameter employed an objective action plan and as such, a modified Failure Mode Effect Analyses (FMEA) method was introduced (Section 7.5 through to Section 7.8). This FMEA approach was applied to the case exemplar with results presented in Section 7.9 and analyses of the results presented in Section 7.10. A chapter summary is then presented in Section 7.11.

## 7.1 Validation Protocol

This section defines the assessment criteria and the validation method employed in assessing how Lean can be employed within MRO to enhance competitive advantage via the developed value delivery system (VDS).

### 7.1.1 Defining the assessment criteria and data collection method.

As earlier established, the application of Lean within the context of the VDS (and not the operational context alone) appropriates Lean's efforts in a way that enhances competitive advantage. Thus, the goal of this validation is to assess the ability of the developed VDS to provide the means through which competitive advantage can be realised.

Since the proposal from this study will require extensive period of time to observe, the validation method proposed by Platts et al., (1998) has been considered to be sufficient and adopted in validating the outcome of this research. Platts et al., (1998), method of evaluation uses three parameters for assessment and validation. These parameters are:

- **Feasibility** – *This refers to whether the proposal can be followed.*
- **Usability** – *This refers to how easily this proposal can be followed especially with regard to identifying problems and the business re-organisation and alignment to address the identified problems*
- **Utility** – *This refers to whether the proposal from this research is able to provide useful results both from an objective view (for example, an action plan) or a subjective view (improvement feedback on the proposal).*

The evaluation of the outcome of this research is validated using these three parameters.

With the parameters used in assessing the outcome of this research established, this section explains the approach in gathering the data of evaluation. It is important that for effective evaluation, appropriate tools and techniques are employed to seek informed opinion and critique from appropriate stakeholders. Some to the tools and techniques that can be used in evaluation include carryout interviews, surveys, focus groups, observations, data extraction (through actual implementation) and secondary data sources. However, due to the significant logistics and amount of time it will require to fully implement and observe the proposal of

this research, the *interview* method was chosen as the means in collecting informed opinion and critique of the proposal using the parameters of feasibility, usability and utility as assessment criteria.

#### 7.1.2 Semi structured interviews.

The interview is a managed and purposeful discussion (Gilman, 2000; Ritchie and Lewis, 2003). In seeking a complete view on a subject, interviews provide a depth of information that perhaps through direct interaction between different parties. Also, through the interview process, the researcher is able to quickly resolve seemingly conflicting information because he/she has the direct opportunity to ask about the apparent conflict. Similarly, relative emphasis (in the form of how strongly the respondent holds that solicited opinion) on a subject is also quicker to establish through the interview process. Thus, considering the logistical and time requirement in evaluating the outcome of this research, employing the interview method to illicit opinion on the feasibility, usability of this research proposal is a sufficient means of validation.

A useful way of describing the types of interviews is a continuum where any particular interview can be placed somewhere between 'unstructured' to 'unstructured' interviews. The 'structured' end of the scale uses 'closed' questions (akin to a questionnaire) while the 'unstructured end of the scale has no guide (akin to an observation). A semi-structured interview is used in this evaluation. A semi-structured interview comprises of a structured set of open questions (informed by literature) which provides a guide to the interviewer and encourages the interviewee to talk freely. Saunders et al (2007) recommends that the semi structured interview have sets of questions to guide 'themes' whilst leaving sufficient freedom for additional questions and information to emerge. A face-to-face interview was conducted. The questions from the interview and responses are transcribed in following sections of this chapter. The outcome of this validation process is used to refine the research proposal

## 7.2 Case Study Selection

This section defines the criteria in selecting the case study that was used for this assessment. The case study selected is consistent with the guide provided by Yin (2014). Yin (2014) suggests that a case study is a preferred option when seeking to answer ‘*how*’ or ‘*why*’ type questions. Case studies are appropriate when the researcher has little control over the development and nature of events as they unfold, and the investigation remains focused upon contemporary events (Redding, 2011). With this phase of the research programme seeking to evaluate the developed VDS as a means of appropriating Lean application in a way that enhances competitive advantage, the area of investigation is contemporary and the semi-structure interview method adopted fulfil the requirement for a case study selection.

Furthermore, when seeking guidance on the number of cases to adopt Yin (2009) suggests that “.....*single case works well if it represents a critical case...or when it represents an extreme or unique case...*” A single case study can also be used when *it is a representative* with studies carried out at *two or more different points in time...*” Although, a single case study has been chosen for the purpose of the evaluation, the combination of the empirical study and the case study (by reason of an interview), will provide the necessary validation within the time and logistical limitations.

However, whilst fulfilling the criteria for a case study, Yin (2014) also highlights four issues with case study which this phase of this research takes into consideration and addresses.

First, Yin (2014) suggests the bias of the researcher in data extraction. In addressing this issue, the assessment criteria from literature provide a structure that helps to mitigate the bias of the researcher. Secondly, Yin (2014) suggests that provide poor basis for scientific generalisation. Again, the purpose of the evaluation and selection criteria of a case study itself (as being *representative*) does not necessarily mean the outcome of the case study is generic, but it provides a scientific basis (or statistical basis where numerous case studies were taken) to make informed judgements. Thirdly, Yin (2014) suggests that case studies can be time consuming. Whilst this may be true, it is possible to still be able to carry-out high quality case studies over the phone and even over the internet (Redding, 2011). Technology advancements and the increasing easy and quick access to information counter the ethnographical and extended participant observation assumptions. Finally, Yin (2014) suggests that case studies are often not able to make assertions to cause and effect

relationships. Again, whilst this may be true, case studies are able to provide supporting evidence to ‘true experiments’ and should be seen as “valued adjuncts to experiments rather than alternatives to them” (Redding, 2011; Yin, 2014).

Based on the above description of the assessment criteria and the data collection protocols, the following sub-section provides a brief description of the organisation chosen.

### Case Study Profile

**Company:** Lufthansa Technik Landing Gear Service.

**Location:** Middlesex, United Kingdom

**MRO Sector:** Component

Lufthansa Technik Landing Gear Service (LTLGS) is a UK subsidiary within the multinational Lufthansa Technik Group. The UK site specialises in maintenance repair and overhaul of landing gears specifically for Boeing aircrafts ranging from single-aisle Boeing 737 aircrafts to larger Boeing (double-aisle) aircrafts like 777 (all variants). LTLGS went through a financial crisis in 2013 posting significant financial losses for the year and as a result initiated a rigorous Lean Transformation Programme. With the strategic location and capability of LTLGS (to service Boeing aircrafts globally), the Lean transformation Programme was fully supported and sponsored by the both the Lufthansa Technik Management and the local LTLGS senior management. LTLGS fit the scope of this research by having recorded an interest in Lean with the intent not to only reverse their financial fortunes but to also enhance their competitive positioning through Lean implementation.

Two people were interviewed from the Senior Management team – the Head of Sales (Former Head of Engineering) and also the Head of Production. It was necessary to interview both Senior Directors from the Senior Management Team as they were best placed within the organisation to know and drive the competitive strategy both with regards to the global market and the changes occurring within the organisation. The interview was conducted in winter of 2015.

### 7.3 Results from the semi-structured interview.

The semi-structured interview was thematic in its approach. The details of the semi-structured are presented in the following section of this chapter. The semi-structured interview sought to explore the following three themes:

- **Understanding the competitive landscape.** Using the Porter's five forces of competition, this theme first seeks to validate the appropriateness of these forces in describing the Landing Gear competitive landscape and then, understand the strength of each of these five forces on the LTLGS.
- **Understand LTLGS's response to the competitive landscape.** This refers to how LTLGS restructured during the transformation programme. The developed MRO value delivery system (VDS) proposed by this research is introduced at this stage testing along the parameters of its feasibility, usability and utility.
- **Establish the competitive profile of the LTLGS.** This theme covers the competitive profile of LTLGS.

The following section is the transcribed details of the semi-structured interview of the Sales Director (former Head of Engineering)

	<b>Transcript of response from the Head of Sales (Former Head of Engineering)</b>
<b>What is the strategic intent of LTLGS</b>	The vision of LTLGS is to be the “... <i>number one Landing Gear MRO business providing our customers with the optimal total cost of ownership (TCO) throughout the Aircraft life cycle...</i> ” This I believe best captures the strategic intent of the organisation.
<b>How do you describe competitive landscape of the MRO industry</b>	The MRO industry is a tightly regulated industry which requires certain approvals (in our case the Part 145 approval) to be able to operate. However, once this approval is provided, you automatically become a valid competitor in the industry. I call this approval the ‘ <i>activation energy</i> ’ because every organisation that has this stamp of authority (at least on paper) is qualified to compete. There are so many organisations around the world with this approval and although the competitive landscape is not even distributed geographically, the competition is quite intense.
<b>Do you think the Porter’s forces of competition best describes or captures the influencing forces of the market?</b>	The demand in the MRO industry is non-elastic in that demand cannot be stimulated (i.e. scheduled overhaul is stipulated by time and usage and cannot be artificially stimulated). Thus, Porters competitive framework captures quite well the forces of competition in the market

**Table 7.1: Key points raised from semi-structured interview (case study)**

	Transcript of response from the Head of Sales (Former Head of Engineering)
<p><b>Having established what competition within MRO comprises off, how does the “threat of new entrants” affect the LTLGS?</b></p>	<p>I don't think the “threat of new entrants” affects MRO organisations based in Europe (and possibly in US) significantly. However, the growing trend within the industry is that there are increased levels of new entrants in Asia (particularly, south-east Asia, China and India). This is more the case because local MRO's are seen as strategic assets by the local governments and therefore the local governments are actively pushing and in some case subsidising these new organisations.</p> <p>Yes, these new facilities might be not have the on experience in the short term but by having the Part 145 license (<i>activation energy</i>) they are already introduced into the competitive environment and with government policies potentially in their favour, local airlines are encouraged to forward their MRO requirements to these facilities. This is trend is not only witnessed in the Component sector but across all sectors of the aviation MRO industry.</p> <p>The bigger fleets and the fastest growing airlines in the world are in Asia and right now LTLGS have almost no potential of getting any Chinese contract because the local policies favour local MRO's. Thus, even though the market is forecasted to grow quite exponentially over the next decade, the geographical spread of this growth is not even globally and the initial indication is that this global growth will benefit more the local MRO's many of whom are new entrants.</p> <p>Furthermore, it remains unclear as to whether these new entrants will begin competing on a global scale. For now, there are a lot of new entrants making the competitive landscape very competitive for LTLGS.</p>

**Table 7.2: Key points raised from semi-structured interview (case study)**

	<b>Transcript of response from the Head of Sales (Former Head of Engineering)</b>
<p><b>What effect does the “supplier bargaining power” have on LTLGS competitive positioning?</b></p>	<p>The singular biggest supplier to LTLGS (and Lufthansa Technik) is Boeing. Latest figure (details withheld) show Lufthansa Technik to be the biggest customer for Boeing in terms of volume of spare parts purchased from Boeing per year. Even though LTLGS (and Lufthansa Technik) remain one of the biggest customers for Boeing, Boeing still holds significant supplier influence. Boeing is the Original Equipment Manufacturers (OEM) and with many airlines preferring OEM products (as opposed to Part Manufactured Approved (PMA) parts) on their aircrafts, the supplier (Boeing still have strong bargaining power with MRO’s. This is not unique to the Component sector alone but to all arms of the aviation MRO industry.</p> <p>However, this supplier bargaining power is significantly less with the airlines than it is with the MRO outfits.</p> <p>The relationship with suppliers is not one of strength for LTLGS and as such restricts LTLGS competitive positioning.</p>

**Table 7.3: Key points raised from semi-structured interview (case study)**

	Transcript of response from the Head of Sales (Former Head of Engineering)
<p><b>What effect does the “customer bargaining power” have on LTLGS competitive positioning?</b></p>	<p>The customer has quite a lot of choice (at least on paper) because any MRO facility that has the capability (Part 145 license) is able to offer exactly the same service. The MRO offering is not an offering that can be differentiated much and as such, it is quite easy for customer to find options.</p> <p>The distinction however lies with the <b>schedule</b> and the <b>availability of assets</b> the MRO organisation is able to offer. Airlines do not want to ground their aircraft longer than they need to and as such, an exchange or loan asset to continue generating revenue with their aircraft whilst their product is being overhauled is a substantial value proposition to the customer.</p> <p>Also, airlines tend to (either independently or because they are subsidised by their local government) offer most of their MRO contract by tender which encourages price competition between MRO’s. It is very rare that even a customer who is satisfied with the current provider will not do subsequent contract offers by tender. As such, there is huge squeeze on price and better conditions (in the form penalty clauses associate with late delivery). This is because it is not only about the price paid for the MRO service but a couple of days late delivery may cost the airline nearly as much in revenue as the price of the overhaul itself. This increases the bargaining power of the customer which they use to push prices down (through the tender purchasing model).</p> <p>This bargaining power of the customer is even more evident in the practice of purchasing department within the airline encouraged to accept the lowest bidder and then, the Fleet/Maintenance management taking over contract negotiations and forcing the MRO organisations to include certain terms in the contract depending on the level of risk exposure each party is willing to take on.</p>

**Table 7.4: Key points raised from semi-structured interview (case study)**

	Transcript of response from the Head of Sales (Former Head of Engineering)
<p><b>What effect does “substitute product” have LTLGS competitive positioning?</b></p>	<p>Landing gears and landing gear overhaul are not going anytime soon. However, the older a fleet is the easier and cheaper it is to buy a set of <i>part-lived</i> landing gears as replacement rather than performing an overhaul on the older gears. To mitigate this, we (LTLGS) tend to treat aircrafts that have gone through their second scheduled overhaul input as not within the core product of the company. This is because we (LTLGS) cannot trust that another overhaul input will happen. Further to this LTLGS, mitigates this challenge through the introduction of new products and capabilities (e.g. newer and different aircraft types).</p> <p>There is a likelihood of time-between-overhaul (TBO) extension due to the use of more reliable materials that require less or no overhaul on future aircrafts. The worst case scenario for LTLGS will be a case where for example the landing gears are made of materials like Titanium (which requires minimum overhaul input) and disposable parts. And as such, the MRO activities will just be an <i>inspection</i> of the Titanium parts and replacement of disposable parts.</p>

**Table 7.5: Key points raised from semi-structured interview (case study)**

	Transcript of response from the Head of Sales (Former Head of Engineering)
<p><b>What effect does the “rivalry between existing customers” have on LTLGS competitive positioning?</b></p>	<p>Rivalry brings prices down. However, the competition between existing customers is not an even. This is due to the available of <i>overhaul slots</i> and <i>asset</i> each MRO is able to provide. These two factors go a long way in determining the specific contracts an MRO is able to tender on.</p> <p>Owning assets is strategic decision by the organisation which is indicative of the competitive intent of the organisation (and the products they wish to compete on). However, these assets are capital expensive which makes the competitive landscape not symmetrical. Nonetheless, the <i>intensity</i> of the rivalry between existing organisations is very high.</p> <p>Conversely, there is no benefit gained from collaborating with other competitors because business once a contract has been won by one MRO it become unavailable to the rest of the market unless there are significant contract breaches. However, it is not unusual for an MRO outfit to win a contract and offload excess events to other MRO facilities. With the demand in the aviation MRO industry completely non-elastic, the competition is quite high.</p>
<p><b>Based on the description of how the forces of competition affect LTLGS, how has Lean benefited LTLGS’s competition position?</b></p>	<p>Since the roll-out of the Lean transformation programme, we have witnessed significant benefits especially with regards to efficiency in terms of labour hours and productivity. These benefits have been crucial in returning the company back to a position of posting operational profits. However, the focus of the transformation program has been shop-floor directed and the effects with regards to enhancing our competitive positioning have been marginal.</p>

**Table 7.6: Key points raised from semi-structured interview (case study)**

	Transcript of response from the Head of Sales (Former Head of Engineering)
<p><b>One of the outcomes of this research is the delineation of the value delivery system which consists of the operational, strategic and economical dimensions. It appears that the application of Lean has been limited to the operational context; do you think widening the context of application to all the other dimensions will contribute positively towards enhancing the competitive positioning of the company?</b></p>	<p>The value delivery system appears to encapsulate all the aspect of the business sufficiently and certainly, the application of Lean beyond the context of the operational dimension will contribute towards our competitive positioning. Take for example the economic dimension, applying Lean thinking into exploiting our <i>asset</i> and <i>capabilities</i> will certainly make us more attractive to the customer and inherently improve our competitive positioning.</p> <p>I think the building block of the value delivery model is sound following this model in its entirety will give has a guide as to how to ensure that our Lean efforts are not too narrow but are consistent with the vision and driving us towards being the number one landing gear shop in the market.</p>

Table 7.7: Key points raised from semi-structured interview (case study)

	Transcript of response from the Head of Sales (Former Head of Engineering)
<p><b>How practical do you think this value delivery system is in enabling you to realise better competitive positioning?</b></p>	<p>Our vision as a company is not to become the lowest cost provider but to be the one that offers the best <i>total cost of ownership</i> to our customers. Whilst I think that is simpler to trace the application of Lean in a cost reduction strategy to the financial bottom-line, I think the route of becoming the best solution provider has a lot of more variables (which are not all cost related). The comprehensive yet simple nature of the value delivery system provides an easy and practical way to make intentional changes that although may take longer, their effects will eventually be reflected in the competitive positioning of the company.</p>

**Table 7.8: Key points raised from semi-structured interview (case study)**

#### 7.4 Analysis and discussion of the results from the semi-structured interview

This section discusses the findings from the semi-structured interview transcribed and presented in Table 7.1 to Table 7.8. The parameters of validation (feasibility and usability) are first discussed and then strengths and weakness as observed by the interviewee is presented.

##### **Feasibility of the approach to Lean application in enhancing competitive advantage**

It became evident from the interview that the approach to Lean application to enhance competitive advantage presented by this research is feasible. This was first confirmed through the clarity provided by the MRO value delivery system (VDS). It was evident from the interview that the MRO VDS encompassed key success criteria for competition - availability of *Asset* and *slot* (capacity). With *Asset* (tangible and intangible) being one of the protocols within economic value dimension, and *capacity* a function of the operational value dimension, it substantiated the comprehensive nature to the VDS. Also, with literature (Chapter 2) and empirical study (chapter 4) indicating that the focus of Lean application was predominantly directed towards the operational value dimension, the disjoint between the expectation (improved competitive advantage) and the focus of Lean efforts (operational value dimension) became readily apparent. As such, validating the **feasibility** in using this research proposal (*that successful Lean application to enhance competitive advantage requires the application of Lean to ALL value dimensions*) to enhance competitive advantage was favourably accepted in its entirety.

##### **Usability of the approach to Lean application in enhancing competitive advantage**

The framework provided by the VDS provided needed clarity as to where Lean efforts are to be directed (all value dimensions) and as such, the *usability* check was substantiated. Although it was noted that it due to the number of key business decision areas (kbda) associated with **all** the value dimensions, it might take longer to trace and determine *what* Lean efforts contribute to the improved competitive positioning. Notwithstanding, the VDS provided a framework that helped to align (business) activities with their competitive intent and aspirations. With the strategic intent of LTLGS to be “...*number one... (with regards to) total cost of ownership...*” the VDS framework provides a means of assessing their performance (within each value dimension and as a whole) and a means to identifying deviations from their vision. As such the *usability* of the framework and the approach to Lean application was also validated.

The outcome of the semi-structured interview with the Head of Sales (former Head of Engineering) at LTLGS provided more insight into how the competitive forces are shaping the landscape and the common practices within the landing gear market (component sector). LTLGS have chosen to compete along the route of best solution through their vision of being the number one provider of total cost of ownership (TCO) for landing gears. The outcome from the semi-structured interview provided satisfactory validation based on *feasibility* and *usability* parameters to this research proposal that achieving competitive advantage through Lean application requires Lean engagement across ALL value dimensions (and not the operational value dimension only).

### **Utility of the approach to Lean application in enhancing competitive advantage**

Whilst there was acceptance and approval of the approach to Lean application for competitive advantage from the semi-structured interview (*feasibility* and *usability*), the *utility* validation sought to for objective outcomes (in the form of an action plan). The following sections of this chapter elucidates on the *utility* validation.

#### 7.5 Using the Failure Mode Effect Analysis (FMEA) to validate the *utility* of the Value Delivery System.

Upon the understanding that has been presented in earlier chapters of this thesis, it is crucial that the actual Lean engagement programme is not only sustainable but encompassing (engages all value dimensions). Literature reveals that organisations whose Lean efforts are underpinned by the Lean philosophy rather than just the application of Lean tools and techniques were are observed to more successful over longer period of time. Although the application of Lean tools and techniques may produce significant gains in the short-term, successful realisation of Lean should be able to withstand the test of time. Thus, premised on the understanding of how Lean can be successfully realised within MRO context (Chapter 5) to enhance competitive advantage (Chapter 6), it is paramount that the gains achieved through Lean introduction is sustainable continually.

Whilst it is clear that there is no ‘*one rule fit all*’ approach that is applicable to all MRO organisations, an action plan that supports the application of Lean to enhance competitive advantage should encompass all value dimensions. A means through which an encompassing

plan can be achieved is by using a modified **Failure Mode Effects and Analysis (FMEA)** method. The forward logic of this method and its ability to identify possible failure modes that may occur in the future makes it a very suitable option in ensuring the alignment and comprehensiveness.

The FMEA method was developed as a formal design methodology in the 1960s by the aerospace industry with the intent of improving reliability and safety. It has since been widely applied in different industries and contexts to enhance product and process reliability. Its popularity as an effective tool in enhancing reliability is premised not only its effectiveness in identifying potential failure modes for a product or process but also its effectiveness in assessing the risk associated with the identified failure modes and prioritise them for corrective action. When used appropriately, FMEA contributes towards:

- Improved reliability of the product or process
- Improved quality of product or process
- Improved safety
- Reduction in wastes and non-value added time or operations
- Reduced product cost (e.g. development cost, design cost, warranty cost etc.)
- Improved consumer satisfaction

It is important to note that whilst the forward logic of the FMEA tool helps to anticipate what failures can occur, the inductive nature of the tool serves as a good indicator of what areas require attention and where the efforts are to be diverted to ensure system reliability. FMEA method is also a good way of identifying deviations from the ideal and aligns strategic (competitive) aspirations with actionable activities. It focuses on prioritising critical failures to improve the safety, reliability, and quality of products and processes.

Whilst this section will not be explicitly tutoring on the FMEA tool, the description presented in this section will give an insight into identifying the deviation from the ideal and prioritising them based on the risk to the VDS as defined by severity, probability of occurrence, and effectiveness of the organisation to control them. The ability to perform this analysis in a practical manner should positively enhance the reliability of the VDS and significantly increase the chances of its long term sustainability. The FMEA approach

presented in this research incorporates the dimensions to the business environment and critical success factors (presented in chapter 5) and combines this with the knowledge of Lean to help identify factors required for successful Lean realisation.

FMEA prioritises the potential failure mode by determining a Risk Priority Number (RPN) in order to perform corrective actions. A numerical scale ranging from 1 to 10 is used to rank the Severity (S) of failure, the likelihood of Occurrence of the failure mode (O) and the probability of failure being Detected (D) (Sawhney et al., 2010). Higher numerical values for S and O indicate a more dire consequence associated with the failure and higher probability of the failure occurring, respectively. On the other hand, higher numerical values for D indicate a higher ineffectiveness of the ability to detect the failure. Failure modes with higher RPN are given higher priority compared with those having lower RPN. RPN is calculated by multiplying severity of the failure (S), the probability of occurrence (O) and the probability of detection (D) in order to determine the risk level of a process as mathematically represented as follows:

$$RPN = S \times O \times D$$

While this approach is widely used, it has come under criticism which in this case, is its suitability to accurately assess a VDS (Narayanagounder and Karuppusami, 2009). Hence Sawhney et al., (2010), proposed a modified FMEA that shifts the focus of the prioritization on the system's ability to detect and manage the failures but allows more focus on prioritising failures based on their ability to detect and manage the failure via Lean tools. Their proposal referred to as the Risk Assessment Value (RAV) places greater emphasis on the Lean practitioner's competence to increase the system's ability to detect and manage Lean failures. It is mathematically represented as:

$$RAV = \frac{S \times O}{D}$$

This modification of the RPN is better aligned with VDS. This is because the RAV denominator, D is the only variable within RAV that is within the direct and immediate influence of the Lean practitioners to impact. Conversely, the RAV numerator is the component of the equation that is typically not under the direct or immediate influence of the

Lean practitioner. Any improvement of this component is typically a by-product of the system's ability to detect a VDS failure. The Severity of the failure (S) and the impact the occurrence (O) a risk event are usually external constraints and in many cases, the counter-measure designed and implemented from the within the remit of the Lean practitioner (D) do not always have the ability to impact the occurrence and/or severity of a risk event. However, it is possible that the counter-measure (or controls) put in place may address the root cause of the failure and therefore reduce the occurrence of the risk event. Even in this case, the ability to impact the probability of occurrence may be medium to long term. The controls have lesser ability to impact the severity of a failure, as severity is independent from either detection or occurrence. In essence, the numerator of RAV represents the risk profile of a VDS failure. This profile is defined by the probability of VDS failure to occur weighted by its consequence (Sawhney et al., 2010).

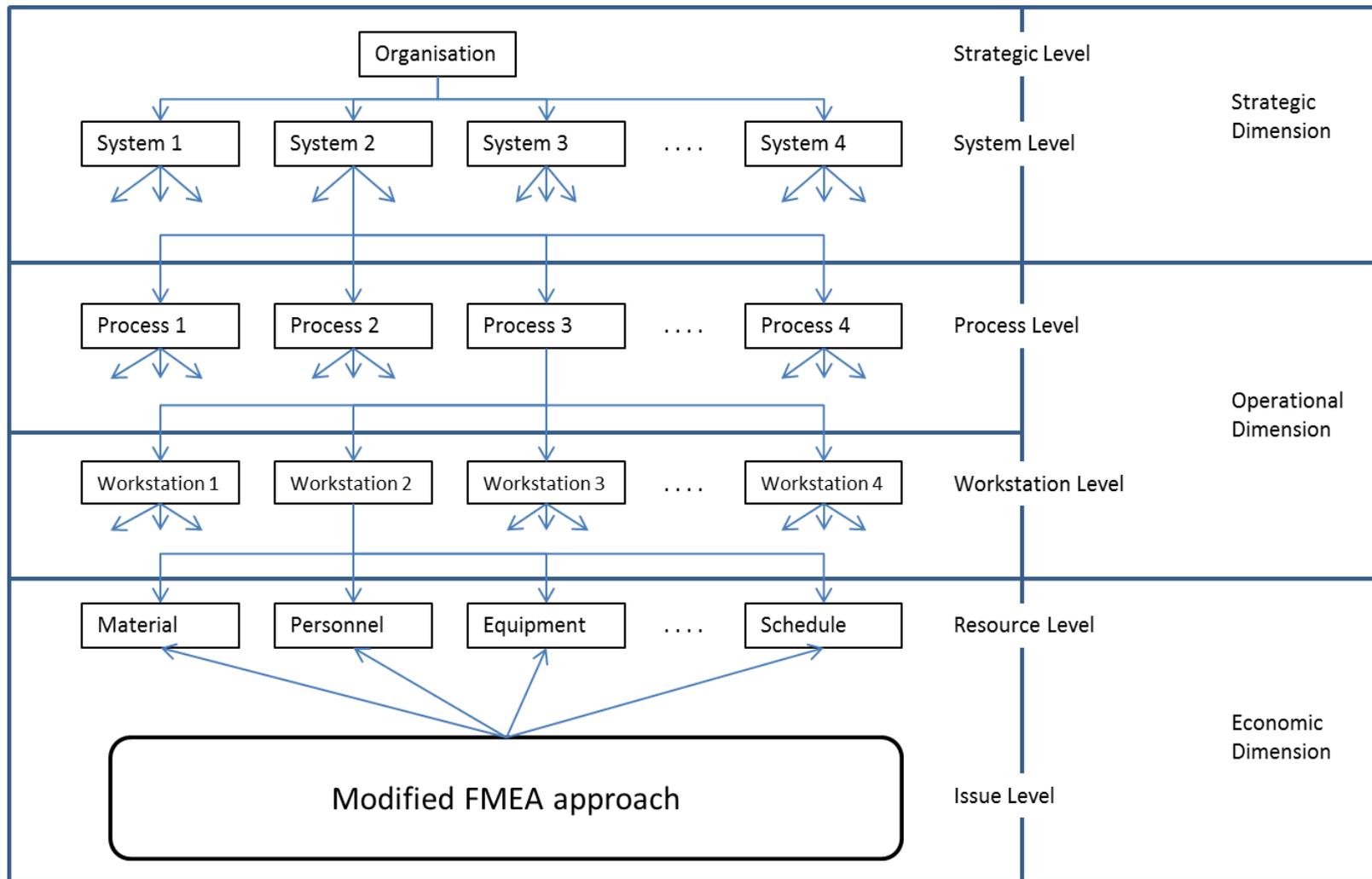
Many of the Lean tools common to both manufacturing and MRO contexts are designed explicitly to detect/control and manage various system conditions. For example, tools like 5S, Production Boards, Proactive Maintenance and Moving Lines help to identify the status of the system. While 5S helps to organise and standardise the work area inclusive of all working tools, materials and supplies such that it will be apparent if a tool is missing or displaced, Production Boards help to highlight the deviations of the production output. Proactive maintenance helps to determine the condition and maintenance programme for all equipment and machinery involved with operations and Moving lines is another Lean tool that helps to highlight stoppages in production lines and manage the system to minimise line stoppages. The modified FMEA provides the more insights in enhancing competitive advantage through successful Lean realisation by presenting the variables that are within the remit of the Lean practitioners and the impact this could have on the business conditions.

#### 7.6 The interaction between FMEA and the Value Delivery System

The reliability of the MRO value delivery system (presented in Chapter 5) consists of the Strategic, Economic and Operational dimensions. Earlier sections of this chapter has already highlighted the need that successful Lean realisation cannot be attained by implementing Lean tools within the Operational context alone (which is most often the case) but its (Lean) focus and engagement should be consistent within the Strategic and Economic dimension equally. Using the FMEA approach, this section helps to provide more insight as to

understanding the reliability of VDS and how it is translated within the framework of the value delivery system. Figure 7.1 provides an overview of the how the FMEA approach interacts with the value delivery system of an organisation.

Research carried out by Sawhney et al., (2010) provides more clarity into the complex network that exists within the value delivery system as captured in Figure 7.1. This framework is represented by six hierarchical levels: Strategic level, System level, Process level, Workstation level, Resource level and Issue level. Within the VDS each of these levels is described as follows:



**Figure 7.1: An overview of the FMEA approach interacts with the value delivery system (VDS) (Sawhney et al., 2010)**

- **Strategic level:** The strategic level focuses on the overall direction in sustaining competitive advantage. It involves understanding the various expectations and realising those expectations via effective and efficient leveraging of resources and capabilities to achieve superior performances. The performance metrics range from market share, customer loyalty, brand recognition, profitability etc.
  
- **System level:** The system level helps to articulate strategy into systems allow the organisation to meet the expectations placed on them by focusing on key competencies and performance metrics. Examples of systems within an organisation include Technical/Engineering, Research & Development, Procurement, Environmental Health, Safety etc. Examples of performance metrics include things like number of requirement change requests, number of design changes, and ratio of research & development expenditure to turnover etc.
  
- **Process level:** Each system can be further delineated into a set of complex interrelated processes. Lean tools are usually quite ‘visible’ at this operational level. Tools like Process and Value stream Mapping are often used at this level to validate processes. The use of such tools can be used to ascertain critical processes that impact the critical systems of the value delivery system. Examples of process level based metrics include Turn-Around-Time (TAT), yield, and inventory turnover etc.
  
- **Touch-point/Workstation level:** Within each process is one or more touch-points/Workstation. Bottlenecks within a process are often the touchpoint/workstation and in order to improve the overall system performance, the critical process and the bottlenecks within the system need to be addressed. The workstation that is the bottleneck of the critical process is identified as the leverage point of these systems. Examples of workstation performance metrics include scrap, rework, cycle time, number of parts produced etc.
  
- **Resource level:** The resource level is the synonymous with the economic dimensions and it represents the resources available in order to meet the various expectations through operational activities. Performance of each workstation is based on its ability

to deal with the four critical resources required for a reliable VDS identified in earlier sections of this chapter – Personnel, Equipment, Material and Schedule. The ability to effectively and efficiently maximise the resource level significantly contributes towards competitive advantage via Lean implementation.

- **Issue level:** Integrating this level into the value delivery system provide a proactive approach that helps the organisation to be able to identify any key issue that may inhibit the positive maximisation of the four critical resource categories. It is therefore paramount to create a knowledge database that allows the organisation to systematically collect information that will inform its evaluation of its performance within each of the four critical resources and any issues causing concern.

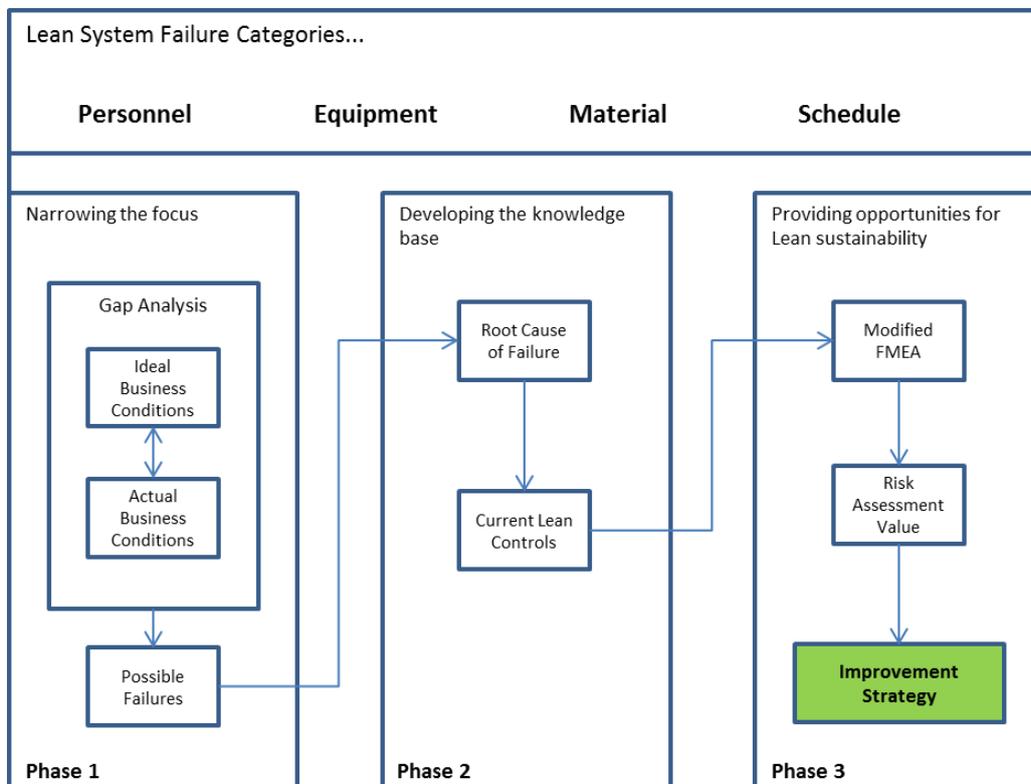
By providing a more detailed description of the MRO value delivery system, it provides more clarity to be able to more effectively identify and address the areas of concern that truly impact the organisation. For example, strategic concerns should be addressed at the strategic level and not at the workstation level. Similarly, process issues should be addressed at that level and not the strategic level providing that the strategy is considered appropriate. The operation of the overall system depends on its processes and, subsequently, the workstations and all the key categories (Personnel, Equipment, Material and Schedule) at each workstation must function properly for the system to be successful. Furthermore, by distilling the value delivery system into this format provides the opportunity to more accurately assess actual business conditions from the assumptions of optimal business Lean conditions. The ability to correctly evaluate the divergence from competitive aspirations helps to inform the counter-measures put in place and subsequently, enhances the reliability of the value delivery system to achieve competitive advantage through Lean implementation. Greater reliability can be attained by systematically and consistently addressing possible failure within all the various levels of the framework particularly the four critical resources at the resource level.

### 7.7 Modified FMEA Methodology to Enhance Competitive Advantage

Although widely accepted, the traditional FMEA approach provides a very linear assessment on the failures in the affect safety, reliability, and quality of products and processes. Whilst this traditional approach may give an indication of the areas of concern, it is limiting in the

fact that it does not provide an accurate sense of prioritisation which does not necessarily take into full consideration the external drivers which already established in earlier sections of this thesis, plays a vital role in the determining the approach the organisation may take towards their Lean engagement. Using the traditional FMEA approach, the areas of concern are prioritised using a Risk Priority Number (RPN). However, the modified FMEA approach proposed by Sawhney et al., (2010) prioritises the areas of concern using a Risk Assessment Value (RAV) which is more suited for VDS. This is because the focus is on prioritising the areas of concern based on the organisations ability to detect and manage the failure using Lean tools. The success of the RAV places a greater emphasis on the Lean practitioner's competence to increase the system's ability to detect and manage Lean failures which makes the VDS more relevant. Altogether, the RAV approach provides a more informed, consistent and structured approach towards enhancing the competitive advantage of the organisation through successful Lean realisation.

Sawhney et al., (2010) modified FMEA approach consists of three phases which are as follows:



**Figure 7.2: An overview of the modified FMEA for VDS (Sawhney et al., 2010).**

(a) Phase 1: Narrowing the focus.

The first phase comprises a gap analysis between the actual business conditions against the ideal business conditions that Lean requires within the four critical components of a workstation. This is a crucial step in enhancing competitive advantage through Lean implementation because the consideration in the gap analysis is the whole business conditions (which extends beyond the operational context alone but the all dimensions to the value delivery system) translated within the context of the four critical components of the workstation – Personnel, Equipment, Materials and Schedule. This approach then provides the opportunity to highlight the weakness of Lean initiatives and provide the basis to know where to direct future efforts. Any ideal business condition required by Lean not satisfied by the current condition will be considered as an area of potential failure. This assessment is an important part of the analysis because it defines and narrows the scope of the effort.

(b) Phase 2: Developing the knowledge base

With the gaps identified, the second phase of the methodology develops a knowledge base that focuses on identifying the pertinent issues within each of the four critical resource categories. The determination of the root causes requires an intense examination of all potential malfunctions in an operation.

(c) Phase 3: Prioritizing opportunities for Lean sustainability

The modification to the FMEA approach to suit VDS is most visible in this phase. Instead of assigning an RPN number as with traditional FMEA approaches, an RAV number derived is more suited for VDS because it provides a more relevant order in prioritising opportunities. Using the modified FMEA approach on an MRO Organisation<sup>††††††††††</sup>, represented in Table 7.9 to Table 7.12 is the outcome of the analysis. However, each column in the FMEA table is described as follows:

- **Column 1 - Lean resource:** This consists of the four critical resources defined earlier – Personnel, Equipment, Material and Schedule.
- **Column 2 - Assumed Business Conditions:** Contained in this column are key assumptions or requirements of Lean for each of the Lean resource categories. The

---

<sup>††††††††††</sup> Organisations' name withheld for confidentiality reasons.

consideration within this column is also influenced by the external drivers exerted on the organisation.

- **Column 3 - Actual business conditions:** This column represents the assessment of the actual business conditions (status) of the organisation. The assessor or Lean practitioner is required to input the extent to which the assumed conditions align with actual business conditions. A rating (numerical on a scale of 1-10) is assigned to any deviation from the Assumed Business Conditions. This is the first step in highlighting the subject as an area for further analysis.

{In the example below, the numerical rating is categorised as: *Never true*: 1-2; *Occasionally true*: 3; *Occasionally true*: 4; *Occasionally true*: 5; *Usually true*: 6; *Usually true*: 7; *Usually true*: 8; *Always true*: 9-10.}

- **Column 4 - Probability of occurrence:** This column captures the likelihood of occurrence of the actual business condition at a given workstation. It is usually an estimate value that is indicative of reality. Similar to the traditional FMEA approach, the rating scale of 1 to 10 is also applicable in this case with a value of 1 indicative of a highly unlikely event occurrence increasing in likelihood up to the value of 10 which is extremely likely to occur.
- **Column 5 - Potential effects:** This column represents the potential outcome of each assumed condition on the overall system..
- **Column 6 - Severity:** This column represents the impact the potential failure would have on the workstation. Since the severity is an independent characteristic regardless of what FMEA approach is taken, the input in this column is an informed estimation that is indicative of reality. Similar to the Probability of occurrence, a rating on the scale of 1 to 10 is used; with a value of 1 meaning the consequences of this particular root cause is insignificant, while a value of 10 yields the most severe repercussions.
- **Column 7 - Potential Root-Cause:** This column provides a list of potential root causes of the assumed condition that indicates weakness in Lean design.

- **Column 8 - Controls:** This column provides a list of recommended Lean tools that can be used to positively influence the VDS. These ‘controls’ are the primary mechanisms where potential improvements can be initiated.
- **Column 9 - Effectiveness of Detection:** this column gives an indication being able to accurately identify the root-cause of a failure. It represents the assessor’s current estimation of an accurate determination of a root cause. The effectiveness of controls is based not only on the ability to measure but also the ability to manipulate root causes. The estimation in this column is also graded on a scale of 1 to 10 with a value of 1 indicative of a control that is effective in capturing and regulating a system's behaviour and a value of 10 indicative of the inability of the control to accurately measure and manipulate the system's performance.
- **Column 10 - Risk Assessment Value (RAV):** The data within this column is calculated based on the inputs of *Probability of Occurrence*; *Severity*; and *Effectiveness of Detection*. RAV derived from these three characteristics represents the potential risks associated with a particular root-cause.

$$\text{Risk Assessment Value (RAV)} = \frac{\text{Probability of Occurrence} \times \text{Severity}}{\text{Effectiveness of Detection}}$$

The lower the RAV value the lower the risk. Higher RAV values represent the highest risks and indicative of the priority in which these risk are to be addressed.

- **Column 11 - Recommendations of Lean projects:** this column provides a list of suggested improvements that can be carried out in order to minimize the risk of system's failure.

## 7.8 Case study – Applying the FMEA on LTLGS

The outcome of the semi-structured interview with the Head of Sales was provided to the Head of Production who fully supported the answers initially provided with no significant addition or deviation. The FMEA approach in validating the *utility* of this research proposal

was presented to the Head of Production which he welcomed and proceeded to fill. The following results (Table 7.9 to Table 7.12) are as provided by the Head of Production.

Resource	ENVIRONMENT					LEAN CONTROLS			IMPROVEMENTS					
Assumed Conditions	Actual Conditions		Probability of Occurrence	Potential Effects	Severity	Potential Root Causes	Controls	Effectiveness of Detection	RAV	RAV Ranking	RPN	RPN Ranking	Recommendation of Lean Projects	
<b>PERSONNEL</b>	Capable and trained Personnel	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	8	SOP not followed Defects	5 3	Training Responsibility Accountability	Training matrix Personnel evaluation	5 4	8 6	5 6	200 96	4 7	Utilise training matrix and personnel evaluation to train personnel
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Effective organisational communication	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	5	Reduced employee morale Ineffective teamwork Organisational/personal conflicts	7	Organisational culture management	No Control	6	5.8	7	210	3	Possess Lean controls to measure organisational culture and management
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Effective job and workplace structure	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	5	Safety issues Quality issues	8 8	Organisational culture management Space shortage	No SOP No 5S	3 2	13.3 20*	3 1	216 144	2 5	Implement 5S and SOP to ensure capable workplace and job design
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Personnel availability	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	7	Rescheduling Wasted time	2 6	Organisational culture management	Policy for missing work Personnel evaluation	7 5	2 8.4	2 4	98 210	6 3	Requires planning to ensure that personnel is available
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
Error free inspection	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	6	Ship defects Customer complaints	8	Human capability Lean awareness	No Poka Yoke	3	16	2	144	5	Implement Poka Yoke	
	Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10												
Multifunction worker	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	4	Lack of ability to meet dynamic demand	4	Cross functional training	Training matrix	6	2.67	9	96	6	Implement training matrix	
	Usually True: 6	Usually True: 7												

		6 Usually True: 7	8 Always True: 9-10											
Mutual respect		Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	6	Reduced employee morale Ineffective teamwork	5	Organisational culture management	No Control	10	3.0	8	300*	1	Process Lean controls to measure organisational culture and management
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
Motivated work force		Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	5	Reduced employee morale Participation and involvement	7	Organisational culture management	No Control	6	5.8	7	210	3	Possess Lean controls to measure organizational culture and management
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											

**Table 7.9: Case Study using the modified FMEA to validate LTLGS Lean application to enhance competitive advantage through its VDS – Personnel Resource (Sawhney et al., 2010) [Adapted]**

\*Indicates the highest risks.

In this example, the RAV approach highlights the “Effective job and work workplace structure” as the highest risk while the RPN value highlights the “Mutual respect” as the highest risk. With the Effectiveness of Detection the only element within the control of the system designers, it serves to reason that the variable where Lean efforts should first be directed to is the variable with the lowest rating of detection thus making this approach better aligned to deliver a reliable Lean System. The same approach applies to all the other Resources – Equipment, Material and Scheduling.

RESOURCE	ENVIRONMENT					LEAN CONTROLS			IMPROVEMENTS					
	Assumed Conditions	Actual Conditions		Probability of Occurrence	Potential Effects	Severity	Potential Root Causes	Controls	Effectiveness of Detection	RAV	RAV Ranking	RPN	RPN Ranking	Recommendation of Lean Projects
EQUIPMENT	Organisation has required capacity	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	8	Excessive overtime Rescheduling	7	Number of machines Machine downtime	Planned Preventive Maintenance initiatives SMED	8	7	2	448*	1	Carry out proactive maintenance activities and implement SMED
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Organisation has the required capability	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	7	Increase production cost due to outsourcing Inability to deliver overtime	5	Expertise in capability Old equipment maintenance	Planned Preventive Maintenance initiatives	7	5	5	245	4	Process capability studies and maintenance activities must be proficient
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10						5	7	2	175	5	
	All tools and equipment are calibrated	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	7	Defects Parts are scrapped	8	No Gauge R&R	Gauge R&R	5	11.2*	1	280	3	Implement gauge R&R
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Organisation has equipment flexibility	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	7	Excessive equipment Large setup times	4	Product mix change Old equipment Setup procedure	C <sub>p</sub> C <sub>pk</sub> ... Maintenance	5	5.6	4	140	7	Process capability studies and maintenance activities must be proficient
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Organisation has a proactive maintenance programme	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	4	High downtime Unplugged events Inability to deliver	7	Ineffective maintenance	No total Preventive Paintenance	6	4,67	6	168	6	Implement total preventive maintenance
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
Organisation have all of the proper	Never True: 1-2 Occasionally	Occasionally True: 4 Occasionally	8	Capacity and capability issues of the	6	Equipment degradation	No total Planned Preventive	8	6	3	384	2	Implement total productive maintenance	

	equipment	True: 3	True: 5		equipment Inability to deliver			Maintenance initiatives						
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Setup is efficient	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	3	Large batch size High lead times Inability to deliver	3	No SMED	SMED	4	2.25	7	36	8	Implement SMED
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											

**Table 7.10: Case Study using the modified FMEA to validate LTLGS Lean application to enhance competitive advantage through its VDS – Equipment Resource (Sawhney et al., 2010) [Adapted]**

RESOURCE	ENVIRONMENT					LEAN CONTROLS			IMPROVEMENTS					
	Assumed Conditions	Actual Conditions		Probability of Occurrence	Potential Effects	Severity	Potential Root Causes	Controls	Effectiveness of Detection	RAV	RAV Ranking	RPN	RPN Ranking	Recommendation of Lean Projects
MATERIALS	There is small and frequent delivery of materials	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	8	Excessive inventory	3	No pull system Supplier issues Poor procurement system	No Kanban system Annual Supplier evaluation ERP system alert	2 3 2	12 8 12	3 5 3	48 72 48	11 10 11	Implement Kanban system Conduct annual supplier evaluation Make ERP system efficient
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Materials are delivered as per schedule	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	5	Production stoppage Modify schedule Inability to deliver	6 4 8	Order not placed on time Supplier delay Poor planning	ERP system alert Receiving manager Planning Manager	5 6 6	6 3.33 6.67	9 13 8	150 120 240	8 10 5	Make ERP system efficient Develop critical to Quality list for receiving end SOP training for receiving and planning manager
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Correct quantity of material are always delivered	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	5	Modify schedule Incomplete order	5 7	Incorrect planning Incorrect order	Receiving manager Planning Manager	6 6	4.17 5.83	12 10	150 210	8 6	Process Lean controls for incorrect order, order change and supplier yield
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	There is always delivery of good quality parts	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	5	Quality issues Excessive WIP Late delivery	7 6 9	Poor Job card Human error	Engineering dept. Quality Inspectors No controls	5 8 10	7 3.75 4.5	7 12 11	175 240 450	7 5 2	Ensure that internal design process is correct in part design and design documentation
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
The system is capable of handling deliveries	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	6	Missing Material Delayed Material	8 5	SOP Training Personnel availability	Receiving SOP-unenforced Human resources training	8 4	6 7.5	8 6	384 120	3 10	Enforce receiving SOP Conduct human resource training Allocate plant managers appropriately according to the plan	
	Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10												
There is correct part movement	Never True: 1-2 Occasionally	Occasionally True: 4 Occasionally	8	Parts not available when required	2 8	SOP Visual controls	Material handler SOP No visual	8 6	2 10.67	14 4	128 384	9 3	Follow material handler's SOP Follow visual boards	

	based on requirement	True: 3	True: 5		Inability to deliver			boards						
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Parts are always properly identified	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	8	Missing Material Lost Material	8	Labelling system Tracking system	SOP Routing sheets	8	8	5	512*	1	Implement SOP and Routing sheets
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											
	Material is delivered to point of use	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	7	Missing Material	9	Lean awareness Space shortage	No SOP No 5S Shadow boards for material	5 3 5	12.6 21* 12.6	2 1 2	315 189 315	4 6 4	Implement SOP and 5S
		Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10											

**Table 7.11: Case Study using the modified FMEA to validate LTLGS Lean application to enhance competitive advantage through its VDS – Material Resource (Sawhney et al., 2010) [Adapted]**

RESOURCE	ENVIRONMENT					LEAN CONTROLS			IMPROVEMENTS					
	Assumed Conditions	Actual Conditions		Probability of Occurrence	Potential Effects	Severity	Potential Root Causes	Controls	Effectiveness of Detection	RAV	RAV Ranking	RPN	RPN Ranking	Recommendation of Lean Projects
SCHEDULE	Forecast is accurate	Never True: 1-2	Occasionally True: 4	5	Excessive inventory Customer delivery not met	5 8	Forecast model Volatile conditions	Forecast accuracy reports	8 7	3.125 5.71	9 6	200 280*	4 1	Ensure that forecast data reports are accurate
		Occasionally True: 3	Occasionally True: 5											
	Customers maintain orders	Usually True: 6	Usually True: 8	7	Product not shipped Complete reschedule	8	Volatile conditions Customer communications	Sales force communication with operations	4	14*	1	224	3	Make sure that sales do not force communication with operations
		Usually True: 7	Always True: 9-10											
	ERP system is capable	Never True: 1-2	Occasionally True: 4	8	Excessive inventory Customer delivery not met	7	Inaccurate data ERP system errors	Physical cycle count	5	11.2	2	280*	1	Ensure that physical cycle count is correct
		Occasionally True: 3	Occasionally True: 5											
	Schedule based on capacity	Usually True: 6	Usually True: 8	7	Constant reschedule Increased batch size Increased setups Delayed delivery	8	Inaccurate data	Physical cycle count	5	11.2	2	280*	1	Implement pull systems
		Usually True: 7	Always True: 9-10											
	No unplanned events	Never True: 1-2	Occasionally True: 4	6	Constant reschedule Increased batch size Increased setups Delayed delivery	7	Volatile conditions Customer communications	Sales force communication with operations	4	10.2	4	168	5	Scheduling must be planned correctly
		Occasionally True: 3	Occasionally True: 5											
Schedule correct time	Usually True: 6	Usually True: 8	4	Constant reschedule Increased batch size	6 8	Inaccurate data	Production reports	6 3	4 10.67	8 3	144 96	6 7	Utilize production reports and routing sheets	
	Usually True: 7	Always True: 9-10												
	Never True: 1-2	Occasionally True: 4	4	Constant reschedule Increased batch size	6 8	Inaccurate data	Production reports	6 3	4 10.67	8 3	144 96	6 7	Utilize production reports and routing sheets	
	Occasionally True: 3	Occasionally True: 5												
	Usually	Usually True:												

		True: 6 Usually True: 7	8 Always True: 9-10											
Schedule to pacemaker process	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	7	Increased scheduling complexity Not smooth flow	7	ERP system errors	Production supervisor	5	9.8	5	245	2	Ensure that scheduling is carried out at only one point to the pace maker process	
	Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10												
Level schedules; volume and mix	Never True: 1-2 Occasionally True: 3	Occasionally True: 4 Occasionally True: 5	3	Constant reschedule Increased batch size Increased setups Delayed delivery	2 4 3 5	No Lean concepts	Heijunka	3	2 4 3 5	11 8 10 7	18 36 27 45	11 9 10 8	Implement Heijunka to achieve production levelling for both volume and product mix	
	Usually True: 6 Usually True: 7	Usually True: 8 Always True: 9-10												

**Table 7.12: Case Study using the modified FMEA to validate LTLGS Lean application to enhance competitive advantage through its VDS – Schedule Resource (Sawhney et al., 2010) [Adapted]**

## 7.9 Analysis of the outcome from the FMEA case study

The exercise carried out as presented in Table 7.9 to Table 7.12 using the modified approach presents a different priority set as compared with the traditional FMEA approach. The outcome from using the RAV approach takes into consideration not only the ideal Lean conditions but also the relevancy to the business in context of all the competitive aspirations and as such provides a more appropriate indication as to the organisations' ability to detect and control the deviations in business and operational conditions.

### **Utility of the approach to Lean application in enhancing competitive advantage**

The relevance to the competitive aspirations of LTLGS (“...number one...in...total cost of ownership...”) realised through its value delivery system (VDS) confirms the *utility* of this research proposal to Lean application. Through the course of this research it has become increasingly clear that difficulty with successful Lean realisation is premised on relevancy and sustainability. Whilst relevancy has to do with Lean efforts that are suited to the context of application, sustainability has to do with ensuring the long term success of the Lean initiatives themselves. The lack of these two criteria with any Lean implementation programme will eventually lead to a decline in the return on Lean efforts which subsequently tend to result in questioning the credibility or reliability of Lean to mitigate pertinent business issues. The decline in the returns from the Lean efforts is not an inherent flaw or weakness in Lean but a lack in the know-how of how to successfully operationalise Lean within the value delivery system (VDS). The modified FMEA presented in this chapter enhancing the know-how by developing a practical approach that systematically operationalises Lean within the VDS and inherently, validates the *utility* to Lean application to enhance competitive advantage.

A secondary outcome of this validation is the ‘scientifically’ development of reliable value delivery systems (VDS). The outcome of using the FMEA approach in developing reliable VDS is that it helps in a critical assessment of the business in relation to the idea by narrowing the focus. The task was the gap analysis allowing the Lean practitioners to critically assess the actual business conditions against the ideal business conditions that Lean requires within the four critical components of the VDS. This helps to avoid the situation where the development of the Lean engagement is based on the expectation of stable business

conditions rather than on more realistic options which tend to be more volatile. Any ideal business condition required by Lean not satisfied by the current condition will be considered as an area of potential failure. This assessment is an important part of the analysis because it defines and narrows the scope of the effort.

The other benefits to using the FMEA approach is that helps in developing a more accurate knowledge base of the business in relation to Lean engagement and external factors. The next task in the using the FMEA tool includes identifying issues in each of the four critical resource categories. The determination of the root causes requires an intense examination of all potential malfunctions in a production environment. The ability to carry out this task effectively will greatly help in prioritising the opportunities for sustainability. Using the modified approach which employs a Risk Assessment Value (RAV) rather than the typical Risk Priority Number (RPN) the opportunities are more clearly identified which relate directly to enhancing the competitive position of the adopting organisation. The RAV values gives a better indication of the ability to detect and control the deviations in business and operational conditions from the ideal and thus better aligns the efforts of the Lean practitioner ensuring that the Lean engagements are more correctly appropriated to enhance competitive advantage.

#### 7.10 Chapter Summary

This chapter has fulfilled the final phase of this research programme by conducting an evaluation of the approach to Lean application within aviation MRO to enhance competitive advantage. This validation was achieved using three main parameters – *feasibility*, *usability* and *utility*. Not only was the *feasibility* and *usability* evaluated, its *utility* was also confirmed via a Failure Mode Effects and Analysis (FMEA) approach within brought synergy to the value dimensions but also alignment with the competitive aspirations of the case exemplar. The case exemplar has stated that the approach is *feasible*, *usable* and it is of tangible use that will bring much needed clarity and focus to their Lean implementation programme. This chapter completely satisfies objective 4 of this research.

## 8. CONCLUSION

This premise for this research is the ubiquitous increase of Lean implementation within the Maintenance Repair and Overhaul (MRO) industry. The increase in Lean adoption albeit recent can be traced back to the 1992 Open Skies agreement and bilateral agreement signed by the US with over 50 nations significantly accelerated the rate of globalisation. MRO organisations have to perpetually maintain an optimum balance between reducing operating costs, supporting the aviation industry to maximise their fleet availability and assuring compliance with regulatory requirements. However, coupled with the global financial crises which started in 2008, the intensity of the global competition within the aviation MRO industry rose to an all-time high. The success of Lean in other industries (particularly the automotive industry) when faced with similar challenges perhaps made it a prevalent choice for organisations within the aviation MRO industry. Although the application of Lean has shown to provide significant efficiency benefits, these benefits did not automatically translate into enhanced competitive positioning. The effects of globalisation and the volatile market thus necessitated this research to understand how Lean can be successfully realised within MRO context in way that facilitates competitive advantage.

First, the status of MRO Lean engagement was first established. This was achieved via two means – a literature review and an empirical study. The literature review was carried out to identify the state-of-the-art of Lean within the MRO industry (presented in Chapter 2). The outcome of the literature review helped to inform the particular area of interest and shape the scope of research. Further to this, an empirical study was carried out with the aim of validating the outcomes from literature but also to engage industry practitioners to further ascertain the influence and focus of Lean application. The details from this empirical study are presented in Chapter 4. This empirical study carried out facilitated by an industry survey provided more insight into aviation MRO Lean status. The synthesis of outcomes from both literature review and the empirical study provided a foundational understanding of aviation MRO Lean status especially with regard to the *interpretation, motivation, focus, extent, strategy* of implementation, *critical success factors* and *inhibitors* as it applies to the aviation MRO context. This understanding not only formed the basis but also informed the following stages of the research.

Furthermore, with the status of MRO Lean engagements indicating that the focus of Lean application is directed more towards its operations where waste is more readily apparent (e.g. shop-floor), it became necessary to explore and identify all the other aspects (inclusive of the operational aspect) that help MRO to fulfil its obligation. This led to the delineation of the means through which MRO delivers value, indeed the MRO value delivery system (VDS). With Lean defined as a *multidimensional* in the sense that it involves the entire organisation in every function (Baines *et al.* (2006), it follows that the successful realisation of Lean should not only be directed towards the operational aspects but to all aspects that contributes in fulfilling its expectations. The delineation of the MRO value delivery system is detailed in chapter 5 of this thesis.

With the aim of this research seeking not only to understand how Lean can be applied within MRO context but how it can be applied to enhance competitive advantage, further research was undertaken to understand what competitive advantage comprised of within aviation MRO context. Using Porter's (1985) framework, competitive advantage is comprised of the attractiveness of the industry and relative positioning of the organisation within the industry. Thus, it became necessary to understand what competitive advantage within the aviation MRO industry comprised of details of which are presented in chapter 6 of this thesis. With competitiveness been at the core of every organisation, it follows that realising better competitive positioning is driven by the appropriateness of the firm's activities through *innovation*, a *cohesive culture* and *good implementation*. Similarly, whilst the application of Lean may have resulted in significant benefits within the aviation MRO context, it is (correct) appropriation that determines if its application will lead to competitive advantage.

Finally, the outcome of this research is validated through a case study as presented in chapter 7 of this thesis. The outcome of this research is assessed based using three parameters: **Feasibility**, **Usability** and **Utility** (Platts et.al., 1998). The *feasibility* parameter tested to see whether the approach as proposed in this research can be followed, whilst the *usability* parameter tested to see how *easy* it was to follow approach towards realising competitive advantage as presented by this research. The *utility* parameter tested to see if approach helped to provide any useful results both objective (action plan) or subjective (feedback that informs the approach). The case study was facilitated by semi-structured interviews which validated the approach proposed by this research and also an action plan in the form of a modified

Failure Mode Effects Analysis (FMEA) profile for the case study company (Lufthansa Technik Landing Gear Service, UK).

Presented in this chapter is first an overview of the research aim and objectives (Section 8.1) followed by the gaps identified in literature and practice (Section 8.2). The contributions to knowledge as evidenced in this research in mitigating these gaps are then presented (Section 8.3). The limitations to the research programme are then elucidated upon (Section 8.4) and the areas for further research highlighted in Section 8.5. This chapter ends with the concluding remarks in Section 8.6

### 8.1 Overview of Research Aim, Objectives and Programme

The main aim of this research was developed in Chapter 3 as:

*Understand how the value proposition of the MRO is realised and present a comprehensive approach as to how Lean can be deployed within this context to enhance competitive advantage. This research will also enable the assessment of performance gaps and aid the user in aligning strategy with the expectation of Lean to achieving competitive advantage.*

In order to achieve this aim, a few objectives were set and completed. These objectives did not only guide the research process but also helped to serve as milestones along the path of delivery the research aim. The key objectives were:

5. Establish the status of MRO Lean engagements through Literature review and empirical study (especially with regard to the *interpretation, motivation, focus, extent, strategy* of implementation, *critical success factors* and *inhibitors* of Lean application).
6. Determine the means through which the MRO value proposition is realised and identify how competitive expectations are mediated through this means.
7. Establish what competitiveness within MRO context comprises of and develop the approach that employs Lean application to enhance competitive advantage.
8. Validate the proposed approach of Lean application to enhance competitive advantage using a case exemplar.

Synonymous to the set objectives, a four phase programme was developed. These phases provided even more detail as to how the objectives were realised and more importantly, helped to show the link and consistency with the research focus. These phases comprised of:

- Phase 1:** Establish the status of MRO Lean engagement via
- Literature review
  - Empirical study facilitated by and industry-wide survey
- Phase 2:** Determine the means through which the MRO value proposition is realised and how this mediates with competitive expectations.
- Phase 3:** Establish what competitive comprises of within the aviation MRO context and develop the approach that employs Lean to enhance competitive advantage within this context.
- Phase 4:** Validate the proposed approach using a case exemplar for the application of Lean in aviation MRO context to enhance competitive advantage.

## 8.2 Gaps in knowledge

The gaps in knowledge we identified via literature review and also via an empirical study. The literature review sought to understand the industry's Lean status and prevalent approaches to Lean engagement. However, the paucity in literature that explicitly described the industry's Lean status necessitated the empirical study which was facilitated through an industry-wide survey. The findings identified from the literature review are:

	Topic	Key Gaps
1	<b>Interpretation of Lean</b>	Lean is widely interpreted as a viable tool within the aviation industry albeit not sufficient by itself to realise all the goals set by the organisation.
2	<b>Motivation of Lean</b>	A major driver for the adoption of Lean in aviation MRO is based on the recorded outcomes of what Lean can deliver in contexts similar to MRO business and performance pressures.
3	<b>The Focus of Lean</b>	The focus of Lean within the aviation MRO industry is predominantly directed towards <i>waste reduction</i> (process variation) as opposed to the creation or the enhancement of <i>value</i> .
4	<b>Extent of the adoption of Lean</b>	There is strong emphasis on the adoption of Lean within the MRO industry, although the extent of its adoption is yet to be ascertained.
5	<b>Lean Implementation strategy</b>	Various implementation strategies have been employed in the adoption of Lean and these strategies, while producing significant benefits in the short term, the sustenance of these benefits in the long term remain unclear.
6	<b>Critical factor for successful Lean Implementation</b>	A critical success factor for Lean realisation extends beyond the deployment of Lean tool and techniques but more importantly, the management (leadership) and the management system that actively encompasses every function and everyone in the organisation.
7	<b>Inhibitors of Lean</b>	<p>The lack of comprehensive understanding on Lean and its capabilities is evident within the aerospace industry thus hindering the successful <i>adaptation</i> of Lean to be plant specific.</p> <p>Incorrectly appropriating Lean due to a lack of understanding of the characteristics of the MRO industry may result in outcomes that will hinder the advancement of Lean in the MRO industry.</p>
8	<b>Strengths and weakness of Existing Literature</b>	More practical engagement with the MRO industry is still required to fill the gaps in knowledge resulting from the paucity in literature regarding the Lean in MRO context.

**Table 8.1: Summary of key gaps identified from the literature review**

The findings identified from the empirical study are:

#	Findings
1	Prevalent MRO operation footprint is more inclined towards its in-house production activities and as such, there is a high tendency for Lean to be viewed and interpreted purely as a waste reduction tool.
2	MRO Lean engagements have resulted in the application of several Lean tools and practices; however, clarity is still needed in how to adapt Lean to the MRO context.
3	The nature of MRO Lean engagements is not holistic in its realisation to facilitate competitive advantage.
4	The outcome of MRO Lean engagement albeit positive still requires clarification as to how to appropriate its application to facilitate competitive advantage.
5	The proliferation of Lean within the transactional aspects of MRO operations is positive; although this outcome has more Lean tools and practices based than Lean thinking based.
6	Clarity is still need in directing the MRO Lean engagements within the infrastructural characteristics of operation to facilitate enhanced competitive positioning.

**Table 8.2: Summary of key findings identified from the empirical study**

The synthesis of the findings from literature and empirical study as presented in Figure 8.1 resulted in the following gaps:

- i) Although there is a positive affinity for Lean in MRO, there is a lack of know-how in how to adapt Lean to MRO context.
- ii) The prevalent approach to Lean engagement within the MRO industry has not been holistic with focus of Lean application mainly directed towards the operational context.
- iii) Clarity is still needed with how Lean can be applied within the aviation MRO context to facilitate competitive advantage.

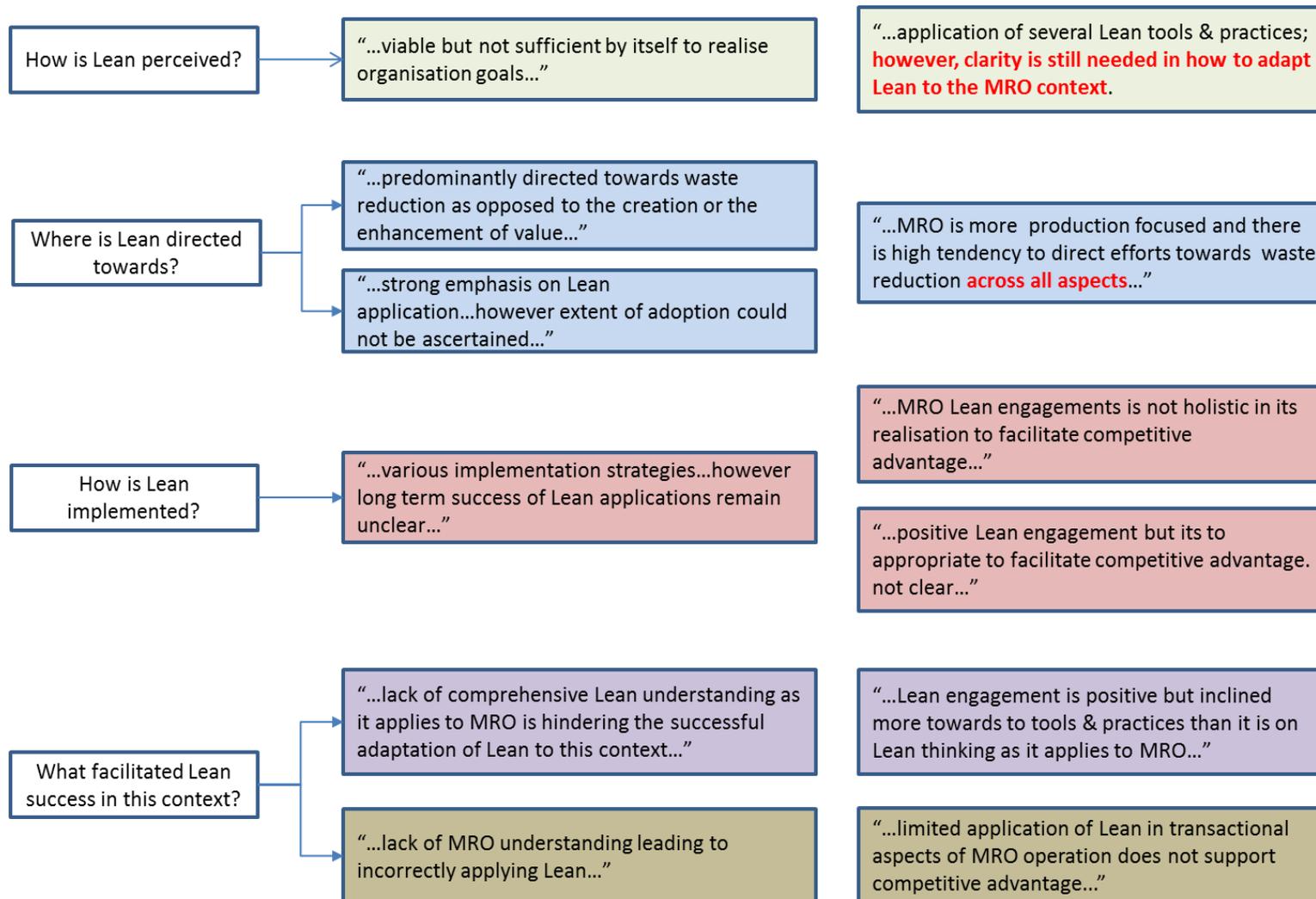
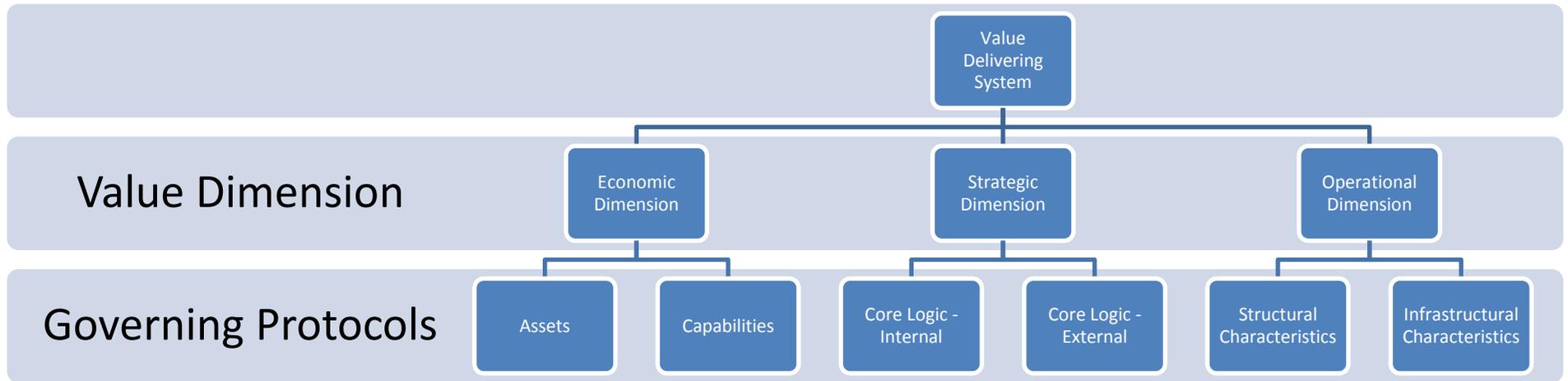


Figure 8.1: Establishing the status of MRO Lean Engagements (comparing Literature and Empirical perspectives)

With these synthesised findings highlighting the prevalent focus of Lean efforts, it became apparent that further investigations into the MRO business environment within which Lean is to be realised is required. This led to the identification of the MRO Value Delivery System (VDS). The VDS represents the framework through which the MRO realises its value proposition. The purpose of Lean application to the MRO context is to facilitate the value that is derived from the value delivery system and as such the application of Lean is not limited to the operational context (in terms of the shopfloor) but to also include all the other value dimensions. Within each value dimension are *governing protocols* which is composed of sets of *key business decision areas* (kbda). The application of Lean tools and techniques are within the key business decision areas. Whilst prevalent application of Lean tools and techniques has been predominantly limited to the operational value dimension (particularly the structural aspect) as evidenced from the literature review and empirical study, this research proposes that the successful application of Lean should involve all *kbda's* across all value dimensions. Figure 8.2 shows the overview of the MRO value delivery system.

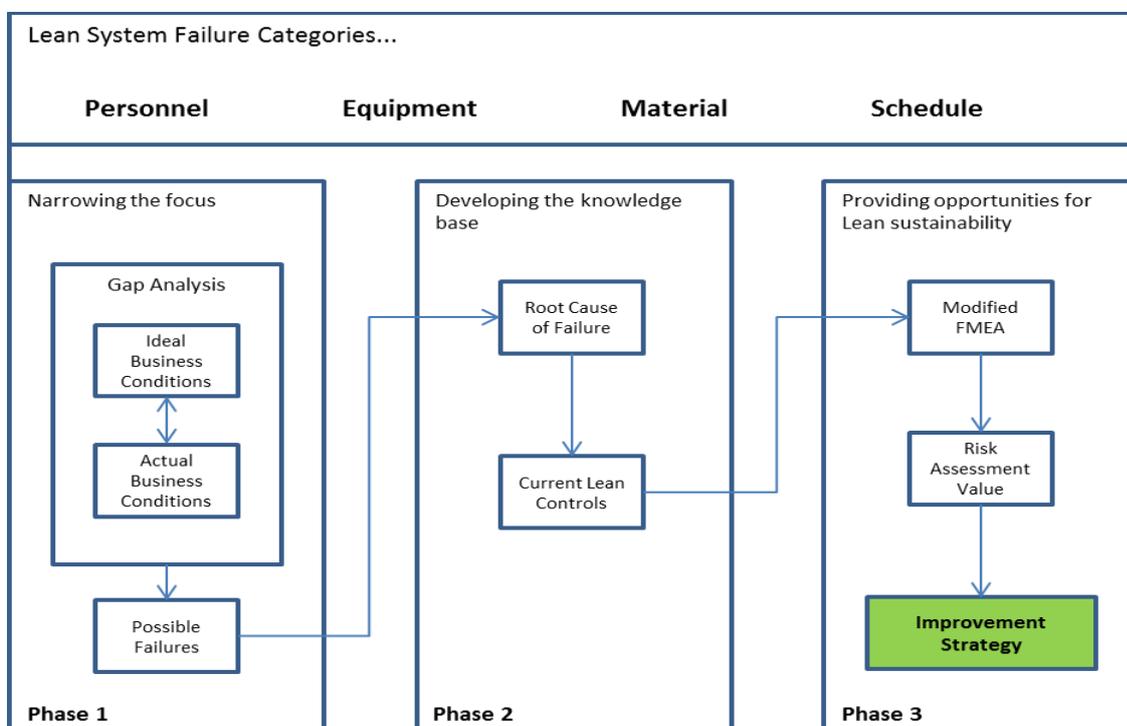
Further to this, it was also observed that clarity was needed in the application of Lean to enhance competitive advantage within aviation MRO context. Literature reveals that whilst the application of Lean may result in significant benefits, these benefits do not always equate to competitive advantage. It is appropriation of the productivity savings created from the application of Lean that contributes to competitive advantage. Clarity was thus needed as to where these productivity savings can be focused. This led to delineating what competitive advantage comprised of within the aviation MRO context (as presented in chapter 6). Structural analysis of the industry using Porter's (1985) model for competitive advantage was used in this delineation. This provided rich insight into competitive routes within the aviation industry which the productivity savings realised through Lean application can be appropriated. MRO organisations respond to the competitive attractiveness of the industry through the competitive route they choose to embark on. This competitive route chosen by an organisation determines the *mode* of Lean realisation within the VDS. Thus, organisations embarking on achieving competitive advantage with regard to cost leadership should employ Lean to end. This may result in driving force for their Lean implementation programme to be cost reduction driven. Regardless of the competitive route, the successful realisation of Lean to this end should encompass all *kbda's* across all value dimensions.



**Figure 8.2: Understanding the aspects to the MRO Value Delivery System**

The final phase of this programme involved validating the approach proposed via this research in realising competitive advantage through Lean application in aviation MRO context. Parameters proposed by Platts (1998) were used for the validation. These parameters include *feasibility*, *usability* and *utility*. These parameters were verified using a case exemplar – Lufthansa Technik Landing Gear services. The feasibility and usability were confirmed via semi-structured interviews with the utility test resulting in an action plan in the form of a modified Failure Mode Effect Analysis (FMEA) profile for the company.

The forward logic and ability of the modified FMEA method to anticipate possible failures and providing an accurate sense of order in which to divert Lean efforts and to ensure that the productivity savings are appropriated in a way that is consistent with the strategic intent of the organisation. As shown in Figure 8.3, the modified FMEA profile consisted of four core elements which include: Personnel, Equipment Material and Schedule (PEMS) which provided a framework that encompassed all the kbda’s across all value dimensions. Whilst further observation is still required, it was noted that the comprehensive nature of this research proposal provided the (case) organisation with the focus, structure and tools to facilitate sustained competitive advantage through Lean implementation.



**Figure 8.3: Overview of the Modified FMEA approach for value delivery system (VDS).**

### 8.3 Summary of the contribution to knowledge

Significant contributions have been made to close the gaps identified both in knowledge and practice through the course of the research detailed in this thesis. The quest in understanding how Lean can be successfully realised within MRO context was fully satisfied but as evidenced in the summary of the gap (Section 8.2), this led to other discoveries which not only add to the body of knowledge in this field but also provides industry practitioners with the tools that will enable them on their Lean journey. This section summarises the primary and secondary contributions to knowledge.

#### 8.3.1 Primary Contribution to knowledge

##### **Successful Lean Realisation engages all dimensions of value**

The main contribution this research makes to knowledge is how Lean can be successfully realised within the aviation MRO context. Where previous studies have explored and suggested that Lean is limited to the operational context alone focusing primarily on the tools and techniques of Lean, this research recognises that successful Lean realisation within the MRO context and indeed within the wider product-centric service context extends beyond the operational context to engage all the other value dimensions of its value delivery system (VDS). The Value delivery system is the means through which value is created and/or delivered. It consists of three dimensions which are: Strategic, Economic and Operational value dimensions. It is the interaction that occurs within all of these dimensions that result in the creation and/or delivery of value. Thus, whilst waste may be more readily apparent in the operational context and hence the predominate focus of Lean to this dimension, successful Lean realisation has to be done within the context of all these dimensions. This is because all of these dimensions play an integral role in the delivery of value and the realisation of the value proposition. However, a decision by an organisation's management to apply Lean tools and techniques does not equate to the strategy of the organisation. Likewise, whilst the application of Lean tools improves the process, it does not always translate into improved capabilities. Therefore for Lean to be successfully realised, it has to engage positively with all the aspects of its value delivery system (Chapter 5).

**Lean application should be appropriated and consistent with the competitive route.**

Furthermore, this research not only sought to understand what successful Lean realisation entailed within MRO context but particularly, how Lean can be applied within this context to enhance competitive advantage. The general assumption that the application of Lean results in overall effectiveness and inherently competitive advantage was investigated through the course of this research. This assumption that Lean application leads to competitive advantage is not an automatic outcome. It was discovered that whilst Lean leads to overall effectiveness, its successes are to be correctly appropriated in order for it to enhance competitive advantage. Conversely, competitive advantage cannot be achieved without considering the competitive landscape of the industry. The competitive edge an organisation gains is achieved within the structural competitive analysis of the industry. An outcome of this research and a contribution to knowledge is the structural competitive analysis of the MRO industry. Although the structural competitive analyses of the industry is not static, the non-elastic nature of scheduled MRO demand (i.e. scheduled MRO demand cannot be stimulated outside of stipulated time or usage limits) substantiates the structural analysis presented. Thus, it became evident that the competitive attractiveness of the industry serve as the overriding determinant in the way the organisation responds. The relationships between the structural analysis of the industry and the MRO value delivery system results in the competitive routes through which organisations seek competitive advantage (Chapter 6). The competitive route chosen by an organisation determines the mode of Lean expression. As such, successful Lean to enhance competitive advantage should endeavour that the productivity savings realised are appropriated and consistent with the overriding competitive route embarked on.

### 8.3.2 Secondary Contributions to Knowledge

Complimentary to realising the main aim of this research, there were some other significant contributions to knowledge identified through the course of this research. These contributions include:

#### **A better understanding of performance measurement in assessing competitive advantage**

Also as an outcome of the research is a better insight into the performance metrics use in assessing the competitive advantage. Traditionally, the metrics that were used in assessing competitive advantage were *Cost*, *Quality* and *Delivery*. However, the paradigm change in

prevalent business models has necessitated the inclusion of *Flexibility* and *Innovation* as key priorities for assessing competitive advantage. Together with Cost Quality and Delivery, these five priorities represent the metrics that are used in assessing competitive advantage. Regardless of the industry or business context, it is important to understand how key performance measures can guide and drive the organisation towards superior results. Not employing the appropriate measures without a strong correlation or linkage to the external factors can lead to mediocre outcomes. Whilst benchmarking and best practices can yield positive results, if not careful, it is possible to be led in a direction that focuses on the same processes and practices of the industry without paying sufficient emphasis on the external factors. Conversely, blind imitation of the best practices and Lean tools could result in Lean realisation that is not congruent with the chosen route of competition.

**Successful Lean realisation entails having a sustainable Lean system.**

One of the validating parameters for the approach to Lean application in aviation MRO proposed by this research involved a *utility* test. The utility test resulted in the use of Lean tool - a modified failure Mode Effects Analysis (FMEA) which provided an action plan that enabled the case exemplar to align strategic intent across the core of all value dimensions. The outcome of this test informs the view of this research that Lean adoption is successful if it delivers in overall effectiveness which is underpinned by a system that is sustainable. The implication of this view for successful Lean realisation is that it ensures that the Lean efforts are sustainable in the long run and not a short-term focus that is not repeatable and or erratic. Whilst it was clear that the structural competitive factors within the industry serves as the overriding determinant for competition, the use of the modified FMEA as a way of aligning strategic intent with the Lean tools and practices applied provides a pragmatic and practical way by which Lean practitioners within MRO can ensure their Lean efforts are (correctly) appropriated to ensure competitive advantage (Chapter 7). The outcome of this research contributes not only to the body of knowledge in Lean application within MRO but also equips practitioners with the know-how in maintaining consistency with the competitive intention.

#### 8.4 Limitations of Research Programme

There were a few limitations that were noted in the course of undertaking this research. Some of these limitations are inherent of the research process itself whilst others related to the research findings. These limitations are detailed as below:

- The nature of the research (i.e. “...*achieving competitive advantage*...”) will require observation over a long period of time. This is more so because the view of successful Lean realisation extends beyond the operational dimension to involve all the other value dimensions of its value delivery system which will require negotiations that occur at the senior management level. As such, the limited time afforded by this research programme will not be sufficient in the complete implementation. Furthermore, although the validation was done using appropriate means and parameters, it will take considerable amount of time before the true competitive positioning of the organisation is known. Also, whilst a case exemplar which satisfied the necessary criteria for the testing provided rich results substantiating the outcomes of this research, a wider test sampling to include all the other sectors within the MRO industry and also geographical locations will provide more insight into the application of Lean to enhance competitive advantage. The logistical complexity coupled with the time restrictions of this programme served as a limitation in achieving this.
- With the paucity in literature regarding the MRO industry, it became necessary to engage the industry in validating the suitability of Lean to mitigate industry challenges. An empirical study facilitated by an industry wide survey was carried out. The essence of carrying out an industry wide survey was to ensure that the empirical study was representative of all the arms of the industry. All the different arms within the MRO industry were represented with an overall response rate of 18%. The most respondents from the Component sector – 26% and the least represented sector being the Engine 11% and the Retrofit Sector – 11%. Whilst this number of respondents was sufficient to undertake the research, it is not fully representative of the entire MRO industry.
- Although the survey questions went through a thorough refinement process to remove ambiguity and militate against bias, being an inductive study, there is still the possibility of bias in the respondent’s responses. Thus, whilst the findings remain valid, caution was

taken in the interpretation of the data underpinned with the perspective that the data provided an informed insight into the prevalent Lean engagements within the industry.

- Finally, the researcher conducted this study on a part-time basis whilst still in full-time employment. This resulted in the research taking longer than it would if conducted by a full-time researcher. Whilst the length of the time it took to complete the research did not affect the quality of the work or the contribution to the body of knowledge, being carried out over a longer period of time resulted in a constant need to re-evaluate the industry's Lean status and prevalent Lean engagement most especially because the research was conducted through a period that witnessed both global financial difficulty and the return to economic stability albeit still in recovery. It is possible for the motivations, focus, intensity for the adoption of Lean to change through these period in response to the external factors affecting the industry – directly and indirectly.

#### 8.5 Recommended Future Work

This outcome of this research makes significant contributions to the Lean effort within the MRO and wider product-centric service environment by elucidating on how competitive advantage can be enhanced through Lean realisation. However, there are areas where further work can be carried out to consolidate these efforts. These include the following:

- The particular scope of the research has been the aviation MRO industry. Whilst the aviation MRO industry is typical of product-centric service industry, it is not fully representative of the product-centric service industry. The increasing rise of servitized business models has meant that traditional manufacturers are no longer competing on the basis of providing the product alone, but on the services which are provided along with product. In some cases, it is the benefit of the product that is provided and not the product itself. All of these newer business models fall belong to the product-centric service community and although the outcome of this research is valid within the aviation MRO industry and by extension, the product-centric service community, the realisation of Lean within this area (Product-centric service industry) still requires further study. For example, whilst the best product means of achieving competitive advantage might not be

available to the aviation MRO industry, it is a dominant means of mediating the external factors within the wider product-centric service environment.

- As indicated in the limitations to the research, an area for future study will be to test and validate the approach proposed in this study to enhancing competitive advantage through Lean realisation within the aviation MRO industry. It is believed by the researcher that a few case studies will be required over a period long enough to validate not only the approach but also the outcome in terms of the market positioning of the organisation.
- The purpose of the FMEA tool in developing sustainable Lean programmes is that it helps to identify the areas of failure and also helps to prioritise where the remedial efforts should be directed. However, more research could be done into improving the decision model captured by the FMEA tool. This practical improvement to this tool could be the automation or even linking it to resource planning tools to aid more real-time analysis. Also, detection scale can also be improved by specifying the types of failsafe mechanisms that should be triggered when limits are exceeded.

## 8.6 Concluding Remarks

This chapter has given an overview into the research undertaken and presented in this thesis. It details the aim and objectives of the research and identified the gaps which this research sought to close. The outcomes of this research in terms of the contributions to knowledge both primary and secondary were presented. The limitations to the research programme were identified which led to the recommendations for future study. This work has made significant contributions to the body of knowledge within the field of Lean as it relates to the maintenance industry and indeed to the wider product-centric service industry.

## 9. REFERENCE

Agus, A., Hajinoor, M. S., (2012), "Lean production supply chain management as driver towards enhancing product quality and business performance: Case study of manufacturing companies in Malaysia", *International Journal of Quality & Reliability Management*, Vol. 29 Iss: 1, pp.92 – 121

Ahmad, S., Schroeder, R.G. and Sinha, K.K. (2003), "The role of infrastructure practices in the effectiveness of JIT practices: implications for plant competitiveness", *Journal of Engineering Technology*.

Aitken, J., Christopher, M. and Towill, D. (2002), "Understanding, implementing and exploiting agility and leanness", *International Journal of Logistics: Research and Applications*, Vol. 5 No. 1, pp. 59-74.

Al-Debei, M. M., & Avison, D. (2010). Developing a unified framework of the business model concept. *European Journal of Information Systems*, 19(3), 359-376.

Al-Kaabi, H., Potter, A., and Naim, M., (2007), "An outsourcing decision model for airlines' MRO activities". *J. of Quality in Maint. Engr*, 13(3), pp. 217-227.

Albert, H.C. Tsang, Andrew K.S. Jardine, Harvey Kolodny, (1999), "Measuring maintenance performance: a holistic approach", *International Journal of Operations & Production Management*, Vol. 19 Iss: 7, pp.691 – 715.

Alejandro, M. and Serebrisky, T. (2006), "Competition regimes and air transport costs: The effects of open skies agreements". *J. Int. Economics*. 70(1), pp. 25-51.

Ali Mohammad Mosadeghrad, (2014),"Why TQM programmes fail? A pathology approach". *TQM Journal*, Vol. 26 Iss 2 pp. 160 – 187.

Almeida, C. (2005), "Low cost maintenance, repair and overhaul providers: an optimum balance to capture the low cost carriers market". MSc Thesis, Cranfield University.

Amartya, S. (1985), *Commodities and capabilities*. Amsterdam New York New York, N.Y., U.S.A: North-Holland Sole distributors for the U.S.A. and Canada, Elsevier Science Pub. Co. ISBN 9780444877307.

Andrew, T., Byard P., Henry P. (2008), “Self-Maintenance works for repair firm”. *Engineering and Technology*, April-May, pp.69-72.

Arora, R. (2002), “Implementing KM – a balanced scorecard approach”, *Journal of Knowledge Management*, Vol. 6, pp. 240-50.

Baines, T., Lightfoot, H., Williams, G. M. and Greenough, R. (2006), *State-of-the-art in Lean Design Engineering: A literature review on White collar lean*. *Engr Manufacture Proc. IMeche J. Part B*, 2006, Vol. 220, No 9, pp 1539-1547.

Baines, T. S, Lightfoot, H. W et al. (2007), “State-of-the-art in Product-Service Systems”. *Engr Manufacture Proc. IMeche J. Part B*, Vol. 221, No 10, pp 1543-1552.

Balakrishnan, R., Linsmeier, T. (1996), Venkatachalam, M. Financial benefits from JIT adoption: effects of customer concentration and cost structure. *Accounting Review*, pp.183-205.

Bamber L., Dale B. G. (2000), *Lean production: a study of application in a traditional manufacturing environment*. *Production Plan Control*. Vol. 11, No 3, pp291–298.

Barney, J., (1991), *Firm resources and sustained competitive advantage*. *Journal of Management* 17, 99-120.

Bartezzaghi, E. (1999), “The evolution of production models: is a new paradigm emerging?”, *International Journal of Production and Operations Management*, Vol. 19 No. 2, pp. 229-50.

Bartholomew, D. (2009), *Lean thinking in aircraft repair and maintenance takes wing at FedEx Express*. Lean Enterprise Institute, [www.Lean.org](http://www.Lean.org).

Bhagwata, R. and Sharmab, M. K. (2007), "Performance measurement of supply chain management: A balanced scorecard approach", *Computers & Industrial Engineering*, Volume 53, Issue 1, Pages 43–62.

Bhasin, S. (2008), "Lean and performance measurement", *Journal of Manufacturing Technology Management*, Vol. 19 Iss: 5, pp.670 – 684.

Bhasin, S. (2012), "An appropriate change strategy for lean success", *Management Decision*, Vol. 50 Iss: 3, pp.439 – 458.

Bicheno, J. (2004), *The New Lean Toolbox: Towards Fast, Flexible Flow*. 3rd ed., PICSIE Books, Buckingham.

Biege, S., Lay, G. and Buschak, D. (2012), "Mapping service processes in manufacturing companies: industrial service blueprinting", *International Journal of Operations & Production Management*, Vol. 32 Iss: 8, pp.932 – 957.

Boeing.com (2006), *Asset Values and the Aircraft Maintenance Revolution*, e-newsletter, Issue 5, available at [http://www.boeing.com/commercial/P2P/pdf/p2p\\_newsletter\\_09-06.pdf](http://www.boeing.com/commercial/P2P/pdf/p2p_newsletter_09-06.pdf) (accessed March, 2009).

Booth, R. (1996), "Accountants do it by proxy", *Management Accounting*, Vol. 74, pp. 48-9.

Borestein S. (1992), *The evolution of U.S Airline Competition*. *Journal of Economic Perspective*, Vol. 6, No 2, pp 45-73.

Bossert, J. (2003), *Lean and Six Sigma – Synergy made in heaven*. *Quality Progress*, American society for Quality Control, 0033-0542X.

Bourne, M., Neely, A., Platts, K., and Mills, J., (2002), "The success and failure of performance measurement initiatives. Perceptions of participating managers", *International Journal of Operations and Production Management*, Volume 22, Number 11, pp1288-1310

Brah, S.A., Tee, S.L. and Rao, B.M. (2002), "Relationship between TQM and performance of Singapore companies", *International Journal of Quality & Reliability Management*, Vol. 19 No. 4, pp. 356-379.

Barriball, K. and While, A. (1994) Collecting data using a semi-structured interview: a discussion paper, *Journal of Advanced Nursing*, 19 (2), pp.328-335.

Bruce, M., Daly, L. and Towers, N. (2004), "Lean or agile: a solution for supply chain management in the textiles and clothing industry?", *International Journal of Operations and Productions Management*, Vol. 24 No. 2, pp. 151-70.

Canaday H., (2009), 'MROs Race to Speed TAT' available from *Aviation Weekly* (online):

[http://www.aviationweek.com/aw/generic/story\\_channel.jsp?channel=mro&id=news/om1209tat.xml](http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=mro&id=news/om1209tat.xml) (Accessed Jan., 2010).

Carpenter, R., & Henderson, A. (2008, January). Keep Them Flying: Find your winning position in the MRO game.

[https://www-935.ibm.com/services/us/gbs/bus/pdf/gbw03020-usen-00\\_keep\\_flying.pdf](https://www-935.ibm.com/services/us/gbs/bus/pdf/gbw03020-usen-00_keep_flying.pdf) (Accessed, 2016)

Chandraprakaikul, W. (2008), *Strategic positioning within global supply chains* (Eng.D Thesis) Cranfield University, Cranfield, UK.

Chesbrough HW and Rosenbloom RS (2002) The role of The Business Model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial and Corporate Change* 11(3), 529–555.

Clare L. Comm Dennis F.X. Mathaisel, (2000),"A paradigm for benchmarking lean initiatives for quality improvement", *Benchmarking: An International Journal*, Vol. 7 Iss 2 pp. 118 – 128.

Cohen M. (2006), "Implications for Service Parts Management in the Rapidly Changing Aviation MRO Market" Helmutt Schmidt University, Germany.

Crute V., Ward Y., Brown S., Graves A. (2003), "Implementing Lean in aerospace – Challenging the assumptions and understanding the challenges", *Technovation*, Vol. 23, pp 917-928.

Daft, J., Albers, S. (2013), "A conceptual framework for measuring airline business model convergence". *Journal of Air Transport Management*, 28, pp. 47-54.

Dalal, A. (2010), "Keep it simple", *Quality Progress*, Vol. 43 No. 9, pp. 24-32.

Department for Business Innovation & Skills (2016), "UK Aerospace Maintenance, Repair, Overhaul & Logistics Industry Analysis". Research paper number 275

Downes, J. and Goodman, J., E. (2003), "Dictionary of Finance & Investment Terms", *Baron's Financial Guides*.

Federal Aviation Administration (FAA). p.8-15. FAA-H-8083-30. [http://www.faa.gov/library/manuals/aircraft/amt\\_handbook/media/FAA-8083-30\\_Ch08.pdf](http://www.faa.gov/library/manuals/aircraft/amt_handbook/media/FAA-8083-30_Ch08.pdf) (accessed January, 2010).

Feld, W.M (2001), *Lean Manufacturing: Tools, Techniques, and How to Use Them*. St Lucie Press, Boca Raton, FL.

Ford H. (1922), *My life and work*. (Kessinger Publishing).

Ford, H. (1926), *Today and tomorrow*. (Doubleday, Page & Company, New York).

Fornell, C., Johnson, M.D., Anderson, E.W., Cha, J. and Bryant, E. (1996), "The American customer satisfaction index: nature, purpose, and findings", *Journal of Marketing*, Vol. 60 No. 4, October.

Garvin, D.A. (1987), "Competing on the eight dimensions of quality", Harvard Business Review, Vol. 65 No. 6, pp. 101-19.

Gavin C. Reid (1993), "Small Business Enterprise: An Economic Analysis". Published by Routledge, ISBN 0-415-05681-0, 978-0-415-05681-6.

George, G., and Bock AJ. (2011), The business model in practice and its implications for entrepreneurship research. Entrepreneurship Theory and Practice, 35(1): 83-111.

George, M.L., and George M. (2003), Lean Six Sigma for service: How to use Lean speed and six sigma quality to improve services and transactions. (McGraw-Hill Professional, New York).

Gillham, B. (2000). The research interview. London: Continuum.

Goldman, S.L., Nagel, R.N. and Preiss, K. (1995), Agile Competitors and Virtual Organisations – Measuring Agility and Infrastructure for Agility, Van Nostrand Reinhold, New York, NY.

Gunasekaran, A. (1998), "Agile manufacturing: enablers and an implementation framework", International Journal of Production Research, Vol. 36 No. 5, pp. 1223-47.

Gunasekaran, A. and Yusuf, Y. (2002), "Agile manufacturing: a taxonomy of strategic and technological imperatives", International Journal of Production Research, Vol. 40 No. 6, pp. 1357-85.

Gurumurthy, A. and Kodali, R. (2011), "Design of lean manufacturing systems using value stream mapping simulation", Journal of Manufacturing Technology Management, Vol. 22 No. 4, pp. 444-473.

Hamel G. Hamel (2000), Leading the Revolution Harvard Business School Press, Boston, Mass.

Hansson, J. and Eriksson, H. (2002), "The impact of TQM on financial performance", *Measuring Business Excellence*, Vol. 6 No. 4, pp. 44-54.

Hao Ma, (1999) "Constellation of competitive advantage: components and dynamics ", *Management Decision*, Vol. 37 Iss: 4, pp.348 – 356

Haque, B. (2003), "Lean Engineering in the aerospace industry". *Proc. Instn Mech. Engrs, Part B: J. Engineering Manufacture*, 217(B10), 1409-1420.

Haque, B., and James-Moore, M. (2004), "Applying Lean thinking to new product introduction". *J. Engng Des.*, 15(1).

Harrison, A., Christopher, M. and Van Hoek, R. (1999), "Creating the agile supply chain", Internal Report, Cranfield University, Bedford.

Hawker Pacific Aerospace "Hawker Pacific Aerospace: Part of Lufthansa Technik Landing Gear Division". <http://www.hawker.com/> (Accessed September, 2009).

Heikkila, J., Cordon, C. (2002), "Outsourcing: a core or non-core strategic management decision". *Strategic Change*, 2002, Vol. 11 pp.183-93.

Hendricks, K.B. and Singhal, V.R. (2001), "Firm characteristics, total quality management and financial performance", *Journal of Operations Management*, Vol. 19 No. 3, pp. 269-285.

Herron, C., and Hicks C., (2008), "The transfer of selected lean manufacturing techniques from Japanese automotive manufacturing into general manufacturing (UK) through change agents", *ICMR2005: Third International Conference on Manufacturing Research, Robotics and Computer-Integrated Manufacturing*, Volume 24, Issue 4, August 2008, Pages 524–531.

Hill, A. and Hill, T. (2009), *Manufacturing Operations Strategy*, 3rd ed., Palgrave-Macmillan, Basingstoke.

Hines, P., Howle, M., and Rich, N. (2004), Learning to Evolve; a review of contemporary Lean thinking. *Int. J. Ops & Prod. Mgmt*, 24(10).

Hsin-Ling H., James W, Yi-Fang Leec. (2008), 'Methodological and conceptual issues confronting a cross-country Delphi study of educational program evaluation'. *Evaluation and Program Planning* Volume 31, Issue 2, May 2008, Pages 191–198.

Iacocca Institute (1991a), *21st Century Manufacturing Enterprise Strategy*, Vol. 1, Lehigh University, Bethlehem, PA.

Iacocca Institute (1991b), *21st Century Manufacturing Enterprise Strategy*, Vol. 2, Lehigh University, Bethlehem, PA.

James-Moore, S.M., and Gibbons, A. (1997), "Is Lean manufacturing universally relevant? An investigative methodology". *Int. J. of Ops. & Prod. Mgmt*. 17(9), pp. 899-911.

Jeffrey, L. and Thomas, C. (2004), *Building Deep Supplier Relationships Building Deep Supplier Relationships*. *Harvard Business Review*, December 2004 Issue.

Jens, J., Dahlgaard Su Mi Dahlgaard-Park, (2006), "Lean production, six sigma quality, TQM and company culture", *The TQM Magazine*, Vol. 18 Iss 3 pp. 263 – 281.

John, A. Parnell, (2006), "Generic strategies after two decades: a reconceptualization of competitive strategy", *Management Decision*, Vol. 44 Iss: 8, pp.1139 – 1154.

John, M. (2005), *Manufacturing Strategy: How to Formulate and Implement a Winning Plan*.

Jon Miller (2005), "What About the 8th Waste", *gemba panta rei*.

Jorge Leon D., (1999), *Toyota Production System and Lean Manufacturing*, Texas A&M University.

Kaplan, R. and Norton, D. (1992), “The balanced scorecard: Measures that drive performance”, Harvard Business Review, 70 (1), pp. 71–99.

Karlsson, C. and Ahlstrom, P. (1996), The difficult part to lean Product development. J Product Innovation Management, 13, 283-295.

Kaynak, H. (2003), “The relationship between total quality management and their effects on firm performance”, Journal of Operations Management, Vol. 21 No. 4, pp. 405-435.

Kidd, P.T. (1994), Agile Manufacturing – Forging New Frontiers, Addison-Wesley, Wokingham.

Kilpatrick, A.M. (1997), Lean manufacturing principles: a comprehensive framework for improving production efficiency. Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, February.

Kinnison H.A. (2004), Aviation Maintenance Management, McGraw-Hill, New York.

Kilpi, J., Vepsäläinen, A.P.J. (2004), Pooling of spares components between airlines. J. Air Transport Management, Vol. 10 pp.137-46.

Kim, L. and Lim, Y. (1988), “Environment, generic strategies, and performance in a rapidly developing country: a taxonomic approach”, Academy of Management Journal, Vol. 31 No. 4, pp. 802-27.

KPMG (2016). “Growth and uncertainty Highs and lows in the Aerospace and Defence Sectors” <https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/growth-and-uncertainty.pdf> Accessed in 2016

Kotha, A. and Orne, D. (1989), “Generic manufacturing strategies: a conceptual synthesis”, Strategic Management Journal, Vol. 10 No. 3, pp. 211-31.

Krishnamurthy, R. and Yauch, C.A. (2007), "Leagile manufacturing: a proposed corporate infrastructure", *International Journal of Operations and Productions Management*, Vol. 27 No. 6, pp. 588-604.

Kros J. F., Falasca, M., Nadler, S. S. (2006), "Impact of just-in-time inventory systems on OEM suppliers", *Industrial Management & Data Systems*, Vol. 106 Iss: 2, pp.224 – 241.

Kvint, Vladimir (2009), *The Global Emerging Market: Strategic Management and Economics*. Routledge.

Laraia, A.C., Moody, P.E., Hall, R.W. (1999), *The kaizen blitz: accelerating breakthroughs in productivity and performance*. The Association of Manufacturing Excellence, Wiley, NY.

Lean Enterprise Institute (2008), *Survey of Lean Community*, available at: [www.lean.org/whoweare/newsarticledocuments/obstacles\\_addendum\\_release08.pdf](http://www.lean.org/whoweare/newsarticledocuments/obstacles_addendum_release08.pdf) (accessed September 2015).

Leea S.G., Maa Y.S., Thimma G. L., Verstraetenb J., (2008), "Product lifecycle management in aviation maintenance, repair and overhaul". *School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore b Technical University of Delft, The Netherlands Volume 59, Issues 2–3, Pages 296–303*.

Lester O. Patterson Jr., Bradford C. Tonder, (2009). *External Strategic Analysis of the Aviation Maintenance, Repair and Overhaul (MRO) Industry and Potential Market Opportunities for Fleet Readiness Center Southwest*. MBA Professional Report, Naval Postgraduate School, Monterey, California.

Lewis, M. A. (2000), *Lean production and sustainable competitive advantage?*. *Int. J. Ops Prod. Mgmt*, 20(8).

Liker, J.K. (1998), *Becoming Lean: Inside Stories of US Manufacturers*. 1998, (Productivity Press, NY).

Liker, J. M. (2004), *The Toyota way*. (McGraw Hill).

Lim, M. (2010), *Environment-Strategy-Structure-Operations (ESSO) Business Model. Knowledge Management Module at Bangor University, Wales*

Linder J.C., and Cantrell S. (2001), *Changing business models*, Institute for Strategic Change, Accenture, Chicago.

Lindic J., Marques da Silva, C. (2011), "Value proposition as a catalyst for a customer focused innovation", *Management Decision*, Vol. 49 Iss: 10, pp.1694 – 1708.

Lozell, M., Lowell, J., Kennedy, M., Levaux, H. (2000), *Cheaper, Faster, Better? Commercial Approaches to weapons acquisition*". Rand Corporation.

Luke T. Miller and Chan S. Park (2004). *Economic Analysis in the Maintenance, Repair, and Overhaul industry: An Options Approach*. *The Engineering Economist* Vol. 49 , Iss. 1,2004

Magretta J (2002) *Why business models matter*. *Harvard Business Review* 80(5), 86–92.

Malone, T. and Sinnett, W. (2005), "Performance management", *Financial Executive*, Vol. 21, pp. 60-3.

Maltz, A., Shenhar, A. and Reilly, R. (2003), "Beyond the balanced scorecard: refining the search for organizational success measures", *Long Range Planning*, Vol. 36, pp. 187-204.

Massachusetts Institute of Technology (MIT), *Lean Aerospace Initiative* (2005), available at: [www.lean.mit.edu](http://www.lean.mit.edu) (assessed January, 2011).

Mathaisel, D.F.X. (2005), *A lean architecture for transforming the aerospace maintenance, repair and overhaul (MRO) enterprise*. *Int. J. of Productivity and Performance Mgt*, 54(8).

Mattias, H. and Olhager, J. (2009), "Lean and agile manufacturing: external and internal drivers and performance outcomes", *International Journal of Operations & Production Management*, Vol. 29 Iss: 10, pp.976 – 999.

Mcauliffe, G. (2007), *Aftermarket: The Ascendancy of Lean in MRO*. Aviation Today, June.

McBride, D. (2003), *The 7 Manufacturing Wastes*, , EMS Consulting Group.

Meadows, S. (1997), *Electronic commerce technology spawns virtual supplier base for obsolete parts*. *National Defence*, Vol. 82 No.533, pp.19-22.

Mecham, M. (2006), *Leaner MRO*. *Aviation Week & Space Technology*, 165(9), pp 48-49.

Melton, T. (2005), *The benefits to Lean manufacturing: What Lean thinking has to offer process industries*. *Instn Chem. Engrs, Part A: Chemical Engineering Design and Research* 83(A6): pp. 662-673.

Michael A. Cusumano (1985), *The Japanes Automobile Industry and Management and Toyota*. Harvard University Asia Center, Business & Economics.

Michael A. Lewis, (2000), "Lean production and sustainable competitive advantage", *International Journal of Operations & Production Management*, Vol. 20 Iss: 8, pp.959 – 978.

Michael J. Stahl, David W. Grigsby. (1997), "Strategic Management". Blackwell Publishing, ISBN 1-55786-650-3, 978-1-55786-650-9.

Michael R. (2012), *5 strategies for increasing speed, improving reliability, and reducing costs – all at the same time*. Available at: [http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Consumer%20Business/us\\_thl\\_smartermro\\_072612.pdf](http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Consumer%20Business/us_thl_smartermro_072612.pdf) (accessed in January, 2014).

Michaels, K. (2007), "Air Transport MRO Market Outlook". Aviation MRO Conference and Exhibition, AeroStrategy, April.

Mika Heinävaara (2010), Lean Applications in Shop Floor Layout Design. Turku University of Applied Sciences, Master's Degree Program in Technological Competence Management, Production Management.

Mintzberg, H. Ahlstrand, B. and Lampel, J. (1998), Strategy Safari: A Guided Tour Through the Wilds of Strategic Management, The Free Press, New York.

Mintzberg, H. and, Quinn, James Brian (1996). The Strategy Process: Concepts, Contexts, Cases. Prentice Hall. ISBN 978-0-132-340304.

Narasimhan, R., Swink, M. and Kim, S.W. (2006), "Disentangling leanness and agility: an empirical investigation", Journal of Operations Management, Vol. 24 No. 5, pp. 440-57.

Narayanagounder, S. and Karuppusami, G. (2009), "A new approach for prioritization of failure modes in design FMEA using ANOVA", Proceedings of World Academy of Science, Engineering and Technology, Vol. 37, January.

Naslund, D. (2008), "Lean, Six sigma and lean sigma: fads or real process improvement methods?", Business Process Management Journal, Vol. 14 No. 3, pp. 269-87.

Naylor, J.B., Naim, M.M. and Berry, D. (1999), "Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain", International Journal of Production Economics, Vol. 62, pp. 107-18.

Neely, A. (1999), "The performance measurement revolution", International Journal of Operations & Production Management, Vol. 19, pp. 205-28.

Neely, A., Gregory, M. and Platts, K. (2005), "Performance measurement system design", International Journal of Operations & Production Management, Vol. 25, pp. 1228-63.

Nune Ravi Sankar, Bantwal S. Prabhu, (2001) "Modified approach for prioritization of failures in a system failure mode and effects analysis", *International Journal of Quality & Reliability Management*, Vol. 18 Iss: 3, pp.324 - 336

Ohno, T. (1988), *Toyota Production System: Beyond Large-Scale Production*. (Productivity Press, Portland, Oregon).

Osterwalder A and Pigneur Y (2001) eBusiness model design, classification and measurements. *Thunderbird International Business Review* 44(1), 5–23

Osterwalder A., Yves Pigneur, Alan Smith, and 470 practitioners from 45 countries (2010). *Business Model Generation*. (Self-published, ISBN: 978-2-8399-0580-0).

Parker, S.K. (2003), Longitudinal effects of lean production on employee outcomes and the mediating role of work characteristics. *J. of Applied Psychology*, Vol. 88 No.4, pp.620-34.

Pateli AG and Giaglis GM (2003) A framework for understanding and analyzing ebusiness models. In *Proceedings of 16th Bled eCommerce Conference on eTransformation*. Bled, Slovenia, pp 329–348.

Pearce, S., Bennet, J. (2005), *How to use a design build approach for a construction project: a client guide*. Chartered Institute of Building (CIOB) available at: [www.ciob.org.uk](http://www.ciob.org.uk).

Peters, Linda, and Saidin, Hasannudin. (2000), IT and the mass customization of services. *International Journal of Information Management*, 20, 1 (January 2000), 103-119.

Pettersen J. (2009), Defining lean production: some conceptual and practical issues. *Journal Quality Technology and Management*. Vol. 21, No 2, pp 127-142.

Platts, K., Mills, J. F., Bourne, M. C., Neely, A. D., Richards, A. H., and Gregory, M., (1998), "Testing manufacturing strategy formulation processes", *International Journal of Production Economics*, vol. 56/57, pp. 517-523.

Porter, M.E. (1980), *Competitive Strategy*, Free Press, New York, NY.

Porter, M.E. (1985), *Competitive Advantage: Creating and Sustaining Superior Performance*, Free Press, New York, NY. (*Republished with a new introduction 1998*)

Porter, M. E. (1997), "COMPETITIVE STRATEGY", *Measuring Business Excellence*, Vol. 1 Iss: 2, pp.12 – 17.

Prince, J. and Kay, J.M. (2003), "Combining lean and agile characteristics: creation of virtual groups by enhanced production flow analysis", *International Journal of Production Economics*, Vol. 85 No. 3, pp. 305-18.

Richardson, J., (2008), *The business model: An integrative framework for strategy execution*. *Strategic Change* 17, 133-144.

Ritchie, J. and Lewis (2003). *Qualitative research practices: a guide for social science students and researchers*. London: SAGE.

Rolls-Royce.com (2004), *Delivering value through services for the 21st century*, available from (<http://www1.rolls-royce.com/service/downloads/service.pdf> (accessed March, 2009)).

Roper, W. (2005), *The missing link of lean success*. Society of Automotive Engineers International.

Roy Andersson, Henrik Eriksson, Håkan Torstensson, (2006) "Similarities and differences between TQM, six sigma and lean", *The TQM Magazine*, Vol. 18 Iss: 3, pp.282 – 296.

Ruy Victor B. de Souza, Luiz Cesar R. Carpinetti, (2014), "A FMEA-based approach to prioritize waste reduction in lean implementation", *International Journal of Quality & Reliability Management*, Vol. 31 Iss: 4, pp.346 – 366.

Sakakibara S, Flynn BB, Schroeder RG, Morris WT (1997), The impact of just-in-time manufacturing and its infrastructure on manufacturing performance. *Management Sci.*, 43: 1246-57.

Santos, F.C.A., (2000), "Integration of human resource management and competitive priorities of manufacturing strategy", *International Journal of Operations & Production Management*, Vol. 20 No. 5, pp. 610-28.

Saunders, M., Lewis, P., and Thornhill, A., (2007), "Research methods for business students", 4th edition ed, Prentice Hall, London.

Sawhney, R. and Chason, S. (2005), Human Behavior Based Exploratory Model for Successful Implementation of Lean Enterprise in Industry. *Perf. Improvement Qrtly*, 18: 76–96. doi: 10.1111/j.1937-8327.2005.tb00334.

Sawhney, R., Subburaman, K., Sonntag, C., Rao Venkateswara Rao, P. and Capizzi, C. (2010), "A modified FMEA approach to enhance reliability of lean systems", *International Journal of Quality & Reliability Management*, Vol. 27 Iss: 7, pp.832 – 855.

Shafer et al., S.M. Shafer, H.J. Smith, J.C. Linder, (2005), The power of business models, *Business Horizons*, 48 pp. 199–207.

Shah, R. and Ward, P. (2003), Lean manufacturing: context, practice bundles, and performance. *J. Ops Mgmt*, 21(2).

Sharifi, H. and Zhang, Z. (1999), "A methodology for achieving agility in manufacturing organisations: an introduction", *International Journal of Production Economics*, Vol. 62 Nos 1/2, pp. 7-22.

Sharifi, H. and Zhang, Z. (2001), "Agile manufacturing in practice: application of a methodology", *International Journal of Operations & Production Management*, Vol. 21 Nos 5/6, pp. 772-94.

Siegel, J. G., Dauber, N. and Shim, J. K.(2005), "The Vest Pocket CPA", Wiley.

Silverman, E. (2000), Oxygen breathes life into obsoletes. *Electronic Buyers' News*, Vol. 1239 pp.104.

Singh, B., Garg, S.K. , Sharma, S.K. and Grewal, C. (2010), "Lean implementation and its benefits to production industry", *International Journal of Lean Six Sigma*, Vol. 1 No. 2, pp. 157-168.

Smart, P.K., Tranfield, D., Deasley, P., Levene, R., Rowe, A. and Corley, J. (2003), "Integrating 'Lean' and 'high reliability' thinking", *Proceedings of the Institution of Mechanical Engineers*, Vol. 217 No. 5, pp. 733-9.

Smith, R. and Hawkins, B. (2004), *Lean Maintenance*. (Elsevier Inc., USA).

Spear, S. and Bowen, H.K. (1999), "Decoding the DNA of the Toyota production system", *Harvard Business Review*, September-October, pp. 97-106.

Stall, S. (2005), Making the business case for MRO. Intech, (Online) available from <http://www.isa.org/InTechTemplate.cfm?Section=Archives4&template=/ContentManagement/ContentDisplay.cfm&ContentID=45715> (Accessed May, 2010)

Stanley E. Fawcett, Sheldon R. Smith, M. Bixby Cooper, (1997), "Strategic intent, measurement capability, and operational success: making the connection", *International Journal of Physical Distribution & Logistics Management*, Vol. 27 Iss: 7, pp.410 – 421.

Stefan Tangen, (2005) "Analysing the requirements of performance measurement systems", *Measuring Business Excellence*, Vol. 9 Iss: 4, pp.46 – 54.

Sullivan, Arthur; Steven M. Sheffrin (2003), *Economics: Principles in action*. Upper Saddle River, New Jersey 07458: Pearson Prentice Hall. p. 272. ISBN 0-13-063085-3.

Swartz, J.B. (1994), *The Hunters and the Hunted – A Non-linear Solution for Reengineering the Workplace*, Productivity Press, Portland, OR.

Tan, K. H., and Platts, K., (2003), "Linking objectives to actions: A decision support approach based on cause-effect linkages", *Decision Sciences*, vol. 34, no. 3, pp. 569-594.

Tangen, S. (2005), "Analysing the requirements of performance measurement systems", *Measuring Business Excellence*, Vol. 9, pp. 46-54.

Tapping, D., Shuker, T., Luyster, T. (2002), "Value Stream Management", (Productivity Press, NY).

Theodore Farris II M., Wittmann M. C., Hasty R. (2005), "Aftermarket support and the supply chain: Exemplars and implications from the aerospace". *International Journal of Physical Distribution & Logistics Management*. Vol. 35, No 1, pp 6-19.

Timmers P (1998) Business models for electronic markets. *Journal on Electronic Markets* 8(2), 3–8.

Tsang, A.H.C., 1998. A strategic approach to managing maintenance performance. *Journal of Quality in Maintenance Engineering* 4 (2), 87–94 (8).

Tsourveloudis, N.C. and Valavanis, K.P. (2002), "On the measurement of enterprise agility", *Journal of Intelligent and Robotic Systems*, Vol. 33 No. 3, pp. 329-42.

Vázquez-Bustelo, D., Avella, L. and Fernández, E. (2007), "Agility drivers, enablers and outcomes: empirical test of an integrated agile manufacturing model", *International Journal of Operations & Production Management*, Vol. 27 No. 12, pp. 1303-32.

Vázquez-Bustelo, D., Avella, L., Fernández, E. (2007), "Agility drivers, enablers and outcomes: Empirical test of an integrated agile manufacturing model", *International Journal of Operations & Production Management*, Vol. 27 Iss: 12, pp.1303 – 1332.

Vokurka, R.J. and Fliedner, G. (1998), "The journey toward agility", *Industrial Management & Data Systems*, Vol. 98 No. 4, pp. 165-71.

Ward, P.T. and Duray, R. (2000), "Manufacturing strategy in context: environment, competitive strategy and manufacturing strategy", *Journal of Operations Management*, Vol. 18 No. 2, pp. 123-38.

Warwick G., (2007), "War on waste: Maintenance". *Flight international*.

William H. Baker Jr., Kenneth Rolfes, (2015). "Lean for the Long Term: Sustainment is a Myth, Transformation is Reality". Florida, Taylor & Francis Group ISBN 13:978-1-4822-5716-8.

William Harley Davidson (2003), "Breakthrough". John Wiley and Sons, ISBN 0-471-45440-0, 978-0-471-45440-3.

Winco Kam-Chuen Yung, Danny Ting-Hong Chan, (2003) "Application of value delivery system (VDS) and performance benchmarking in flexible business process reengineering", *International Journal of Operations & Production Management*, Vol. 23 Iss: 3, pp.300 - 315

Wise, R., and Baumgartner, P. (1999), "Go Downstream: the New Profit Imperative in Manufacturing". *Harvard Business Review*: pp. 133-141.

Womack, J. P. and Jones, D. T. (1996), *Lean Thinking*. (Simon & Schuster, New York).

Womack, J. and Jones, D. (2005), "Lean Solutions". Simon & Schuster, London.

Womack, J. P., Jones, D.T. and Roos, D., (1990), "The machine that changed the world. (Maxwell Macmillan International, New York).

Womack, J.P., Jones, D.T. (2003), “Lean Thinking: Banish Waste and Create Wealth in Your Corporation”. (Free Press, New York, NY).

Wouter, W. A., Beelaerts, V. B., Elferink, H. A. and Curran, R., (2009), ‘Measuring Value Creation; A case study in the MRO Business’ 9th AIAA Aviation Tech. Integration, and Ops. Conference, AIAA-2009-7101, 21-23 Sept., South Carolina, USA.

Yile, L. U., XueHang, X. and Zou L., (2008), ‘Lean Maintenance framework and its application in clutch maintenance’ in International Conference on Information Mgmt, Innovation Mgmt and Industrial Engineering. ICII, 19-21 Dec., IEEE, Taipei, pp 230-232.

Yin, R. K. (2014), Case Study Research: Design and methods (5th ed), Sage, London UK.

Yusuf, Y.Y. and Adeleye, E.O. (2002), “A comparative study of lean and agile manufacturing with a related survey of current practices in the UK”, International Journal of Production Research, Vol. 40 No. 17, pp. 4545-62.

Zott, C. and Amit, R. (2010), “Business model design: An Activity System Perspective Long Range Planning”, 43 (2010), pp. 216–226.

Zott et al., (2011), “The Business model: Recent Developments and Future Research”, Journal of Management, 37 (2011), pp. 1019–1042.

10. APPENDIX

APPENDIX 1: EMPIRICAL SURVEY DESIGN

Please, either attach your business card or complete the following information.

- Name:
Company:
Position:
Job description:
Plant/Building/Department:
Address:
Phone:
Email:

Section 1:

WHAT MRO SECTOR DOES YOUR COMPANY BELONG TO?
(PLEASE TICK THE OPTION(S) THAT APPLY)

- Heavy Maintenance Visit [YES] [No]
Engine Overhaul [YES] [No]
Component Overhaul [YES] [No]
Line Maintenance [YES] [No]
Avionics [YES] [No]
Modifications and Retro-fits [YES] [No]

OTHER (PLEASE

SPECIFY).....

PLEASE INDICATE WHICH OF THE FOLLOWING OPERATIONS ARE INTERNALLY CARRIED OUT IN YOUR COMPANY?

(PLEASE TICK THE OPTION(S) THAT APPLIES)

- DISASSEMBLY - [YES] [No]
STRIPPING/REMOVAL OF SURFACE FINISHES - [YES] [No]
MEASUREMENT - [YES] [No]
INSPECTION - [YES] [No]
MACHINING - [YES] [No]
PLATING - [YES] [No]
NON-DESTRUCTIVE TESTING - [YES] [No]
PART-PEENING - [YES] [No]
SPECIAL COATING - [YES] [No]
ASSEMBLY - [YES] [No]
PAINT - [YES] [No]
STRESS RELIEVING/DE-EMBRITTLMENT BAKE - [YES] [No]
MANUFACTURE - [YES] [No]
RE-WIRING - [YES] [No]

➤ **TEST (E.G. FLIGHT, ELECTRIC) -** [YES] [NO]

**WHAT EXTERNAL SERVICES DO YOU OFFER YOUR CUSTOMER(S)?**

**(PLEASE TICK THE OPTION(S) THAT APPLIES)**

- **INSTALLATION OF PRODUCT** [YES] [NO]
- **PRODUCT TRAINING** [YES] [NO]
- **CUSTOMER HELPDESK (SUPPORT)** [YES] [NO]
- **BREAKDOWN REPAIR** [YES] [NO]
- **SPARE PARTS SALES** [YES] [NO]
- **PREVENTIVE MAINTENANCE** [YES] [NO]
- **DIAGNOSTICS** [YES] [NO]
- **PRODUCT DISPOSAL** [YES] [NO]
- **PROVISION OF LABOUR** [YES] [NO]
- **SYSTEM INTEGRATION** [YES] [NO]
- **FINANCING** [YES] [NO]
- **ADVICE/CONSULTING** [YES] [NO]
- **NON AEROSPACE** [YES] [NO]

**OTHER**

**(PLEASE**

**SPECIFY).....**

**WHICH OF THE FOLLOWING (ACTIVITIES) HAS BEEN IMPLEMENTED IN YOUR COMPANY?**

**(PLEASE TICK THE OPTION(S) THAT APPLIES)**

- SIX SIGMA** [YES] [NO]
- CONTINUOUS IMPROVEMENTS** [YES] [NO]
- LEAN MANUFACTURING/MAINTENANCE** [YES] [NO]
- AGILE MANUFACTURING/MAINTENANCE** [YES] [NO]
- KAIZEN** [YES] [NO]
- JUST-IN-TIME MANUFACTURE/MAINTENANCE** [YES] [NO]
- BUNDLED ASSET MANAGEMENT PROGRAMMES** [YES] [NO]
- 5S** [YES] [NO]
- TPM** [YES] [NO]
- OVERALL EQUIPMENT EFFECTIVENESS** [YES] [NO]
- MAPPING (PROCESS, VALUE, LEAD)** [YES] [NO]
- INVENTORY MANAGEMENT** [YES] [NO]
- VISUAL MANAGEMENT** [YES] [NO]
- ROOT CAUSE PROBLEM SOLVING** [YES] [NO]
- POKAYOKE** [YES] [NO]
- SELF AUDITS** [YES] [NO]
- STORYBOARDING** [YES] [NO]
- KANBAN** [YES] [NO]
- TAKT TIME** [YES] [NO]
- VALUE FOCUSED THINKING** [YES] [NO]
- SUPPLIER CONSOLIDATION/ASSOCIATIONS** [YES] [NO]
- OPEN BOOK MANAGEMENT** [YES] [NO]

**OTHER**

**(PLEASE**

**SPECIFY).....**

**PLEASE INDICATE WHERE, IN YOUR OPINION, THE MOST BENEFITS HAVE BEEN SEEN AS A RESULT OF IMPLEMENTING THE ABOVE TOOLS?**

**(PLEASE GRADE THEM IN ORDER OF IMPORTANCE. NOTE: 1 – MOST BENEFICIAL; 3 LEAST BENEFICIAL)**

	<b>(LEAN) BENEFITS</b>
<b>LABOUR PRODUCTIVITY</b>	[1] [2] [3]
<b>QUALITY</b>	[1] [2] [3]
<b>LEAD TIME / TURN-AROUND-TIME (TAT) REDUCTION</b>	[1] [2] [3]
<b>SCRAP AND REWORK COST</b>	[1] [2] [3]
<b>PRODUCTION COST</b>	[1] [2] [3]

Section 2:

**OPERATIONAL SYSTEMS ARE GENERALLY CLASSIFIED INTO THE FOLLOWING CHARACTERISTICS. PLEASE INDICATE HOW SUCCESSFUL (LEAN) TOOLS AND TECHNIQUES HAS BEEN IN THESE AREAS.  
(PLEASE TICK THE OPTION(S) THAT APPLIES. NOTE: 1 – LEAST SUCCESSFUL; 5 – MOST SUCCESSFUL)**

	<b>OPERATIONAL CHARACTERISTIC</b>	<b>SUCCESS RATING</b>
<b>STRUCTURAL</b>	<p><b><u>PROCESS AND TECHNOLOGY</u></b></p> <p>Increased emphasis on automated systems/varying range of technology, information systems and databases to enhance product conformance, efficiency, communication and customer interaction. Emphasis on <b>production (shop-floor layout), processes</b> e.g. machine centres.</p>	<p>[1] [2] [3] [4] [5]</p>
	<p><b><u>CAPACITY</u></b></p> <p>Increased emphasis on the interaction between <b>Human Resources, Technology</b> and <b>Supply Chain</b> to match demand.</p>	<p>[1] [2] [3] [4] [5]</p>
	<p><b><u>FACILITIES</u></b></p>	<p>[1] [2] [3] [4]</p>

INFRASTRUCTURAL	<p>Increased emphasis on <b>business proximity to market/customer</b>. Re-organisation of business into network of smaller business units. Possible ‘showcase’ of the facility.</p>	[5]
	<p><b><u>SUPPLY CHAIN POSITIONING</u></b></p> <p>Increased emphasis over the range of activities to be carried out by the company i.e. outsourcing, in-sourcing, subcontracts, Make vs Buy etc. Emphasis on the span of process (vertical integration).</p>	[1] [2] [3] [4] [5]
	<p><b><u>PLANNING AND CONTROL</u></b></p> <p>Increased emphasis on the flow of materials in and through the company e.g. Enterprise Resource Planning (ERP), Materials Requirements Planning (MRP) 2, Optimised Production Technology (OPT), Period Batch Control (OPC), Kanban ConWip, Batching, Jobbing, Flow etc. Increased emphasis on the optimisation of product availability and interaction between <b>information capacity</b> and <b>stock</b>.</p>	[1] [2] [3] [4] [5]
	<p><b><u>HUMAN RESOURCES</u></b></p> <p>Increased emphasis on worker skills, defined routines, training, motivation, attitudes, values and culture of the organisation.</p>	[1] [2] [3] [4] [5]

<p><b><u>QUALITY CONTROL</u></b></p> <p>Increased emphasis on quality conformance (to reduce scrap), product assurance and customer satisfaction. E.g. ISO 9000/1, ISO 1401, Statistical Process Control (SPC), Statistical Quality Control (SQC) etc.</p>	<p>[1] [2] [3] [4] [5]</p>
<p><b><u>NEW PRODUCT / SERVICE INTRODUCTION</u></b></p> <p>Increased emphasis on the product range(s) and/or supporting services.</p>	<p>[1] [2] [3] [4] [5]</p>
<p><b><u>PERFORMANCE MEASUREMENT</u></b></p> <p>Increased emphasis and/or change in performance measuring methods e.g. from piece-work to cell based incentives. Internal measures such as Machine utilisation, worker utilisation, WIP, Door-Door time etc</p>	<p>[1] [2] [3] [4] [5]</p>
<p><b><u>SUPPLIER RELATIONS</u></b></p> <p>Increased emphasis and change in the sourcing of resources/materials e.g. from single sourcing to multi sourcing. Integration of external and internal supply chains. Increased emphasis on responsiveness of supply chain.</p>	<p>[1] [2] [3] [4] [5]</p>
<p><b><u>CUSTOMER RELATIONS</u></b></p>	<p>[1] [2] [3] [4]</p>

	Increased emphasis on customer interaction and feedback.	[5]
--	--	-----

**WITH REGARDS TO YOUR BUSINESS OPERATIONS, PLEASE INDICATE THE OPERATIONAL CHARACTERISTIC YOU ARE MOST PROUD OF.  
(PLEASE TICK THE OPTION(S) THAT APPLIES. NOTE: 1 – LEAST PROUD OF; 3- MOST PROUD OF)**

PROCESS AND TECHNOLOGY	[1] [2] [3]
CAPACITY	[1] [2] [3]
FACILITIES	[1] [2] [3]
SUPPLY CHAIN POSITIONING	[1] [2] [3]
PLANNING AND CONTROL	[1] [2] [3]
HUMAN RESOURCES	[1] [2] [3]
QUALITY CONTROL	[1] [2] [3]
PRODUCT / SERVICE RANGE	[1] [2] [3]
NEW PRODUCT / SERVICE INTRODUCTION	[1] [2] [3]
PERFORMANCE MEASUREMENT	[1] [2] [3]
SUPPLIER RELATIONS	[1] [2] [3]
CUSTOMER RELATIONS	[1] [2] [3]

**OTHER (PLEASE SPECIFY).....**

**PLEASE INCLUDE ANY OTHER COMMENTS IN THIS BOX.**

***All responses should be sent to:***

*Post: Manufacturing Department (Building 50), Cranfield University, Cranfield, Bedfordshire. MK43 0AL.*

*Fax: 01234 754 605*

*Email: [p.o.ayeni@cranfield.ac.uk](mailto:p.o.ayeni@cranfield.ac.uk) / [p.d.ball@cranfield.ac.uk](mailto:p.d.ball@cranfield.ac.uk)*