TOTAL PRODUCTIVE MAINTENANCE (TPM) IMPLEMENTATION BASED ON LEAN MANUFACTURING TOOLS

BY

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ABSTRACT

This research was aimed to explore the implementation of Total Productive Maintenance (TPM) pillars and Lean Manufacturing (LM) tools as well as to investigate barriers and enablers in their implementations in Indonesian manufacturing industries. Another primary focus of this research was to develop reference models for both measurement and structural TPM pillars, LM tools and Manufacturing Performance (MP). A total of 132 questionnaires were sent to 132 manufacturing companies from 5 different industrial estates in Jakarta, Tangerang, Bekasi, Cilegon and Batam. A total of 108 questionnaires returned and only 91 were found suitable to be analysed. The findings indicate a reasonably good implementation of TPM and LM in Indonesian manufacturing industries. However, TPM performance in terms of Overall Equipment Effectiveness (OEE) value seems to be unsatisfactory, with the average value of 52.5 compared to the world class OEE with a value of 85%. There were 5 enablers and 7 barriers significantly influencing the success of TPM implementation, while 4 enablers and 5 barriers were found in the LM tools implementation. Six pillars of TPM were considered to be valid, reliable, and significant to represent the TPM implementation in Indonesia, while the other two were found to be nullified. All of the eight LM tools were also considered to be valid, reliable and significant. TPM was found to have a strong correlation with LM but has a weak correlation with MP. On the other hand, TPM has an indirect and moderate influence on MP through OEE and also LM tools. There was also evidence indicating that OEE has a strong direct influence towards MP. Lean manufacturing also has a moderate correlation with MP. The TPM pillars and LM tools have a significant and positive impact to MP simultanously. The influence of both on MP is 60.9% (R^2 = 0.609) in proposed model but increased to 74.8% in the revised (final) model (R^2 = 0.748). It also means that 74.8% variability of MP can be explained by TPM and LM, while 25.2% can be explained by the others. This model can be considered as a reference on the impact of TPM pillars and LM tools implementation over manufacturing performance in Indonesian manufacturing industries.

خلاصة البحث

لقد تم بالفعل تأسيس أبحاث حول TPM و LM ولكنها لا تزال نادرة للغاية في الدول النامية، وخاصة إندونيسيا. على الرغم من أن التطوير الحالي لتطبيق أدوات LM و TPM أصبح واسع الانتشار على نحو متزايد في إندونيسيا، ولكن لا يزال مستوى نجاح تطبيق أدوات LM و TPM وتأثيرها على أداء التصنيع غير معروف وبحاجةٍ إلى إجراء أبحاث شاملة. سعى هذا البحث إلى استكشاف تنفيذ ركائز TPM وأدوات LM والتحقيق في الحواجز وعوامل التمكين لتطبيقها في الصناعات التحويلية الإندونيسية. كان التركيز الأساسي الآخر لهذا البحث هو تطوير نماذج مرجعية لكل من القياس والهيكلية لركائز TPM ، وأدوات LM و MP (أداء التصنيع). حيث تم إرسال 132 استبياناً إلى 132 شركة صناعية من خمسة مناطق صناعية مختلفة في جاكرتا وتانجيرانج وبيكاسي وسيليجون وباتام. حيث تم إعادة 108 ، بينما كان 91 استبياناً فقط مناسبةً للخطوة اللاحقة. تشير النتائج إلى وجود ممارسات TPM و LM جيدة في الصناعات التحويلية الإندونيسية. هناك خمسة عوامل تمكينية و سبعة حواجز يمكن اعتبارها مؤثرة في نجاح تطبيق TPM. أما بالنسبة لتنفيذ أدوات LM ، هناك ستة عوامل تمكينية وخمسة ركائز تم اعتبارها بالغة التأثير. تقريباً تُعَدّ جميع ركائز TPM الثمانية صحيحة وموثوقة وذات أهمية لتمثيل تطبيق TPM في إندونيسيا. بينما كان اثنان فقط من الركائز غير صالحَين. تم اعتبار جميع أدوات LM الثمانية موثوقة، مهمة ومؤثرة. كانت علاقة TPM قوية مع LM ولكن لديها علاقة ضعيفة مع MP. ولكن من جهة أخرى، TPM له تأثير غير مباشر على MP عبر OEE. ووجد أيضاً أدّلة على أن OEE له تأثير قوي ومباشر على MP. أظهر LM علاقة معتدلة مع MP. وبالتالي فإنّ ركائز TPM وأدوات LM لها تأثير كبير وإيجابي على MP بشكل تزامنيّ. يبلغ تأثير كلاهما على MP بقيمة 60.09% (R^2= 0.609) في النموذج المقترح لكنه ارتفع إلى 74.8% في النموذج المعدّل (النهائي) (R^2 = 0.748). وهذا يعني أيضًا أنه يمكن تفسير تغير MP من خلال TPM و LM و OEE بينما يمكن تفسير 25.2% من قِبَل الآخرين. يمكن أن يكون هذا النموذج نموذجاً للتنبؤ بأثر ركائز TPM وأدوات LM على أداء التصنيع في الصناعات التحويلية الإندونيسية.

APPROVAL PAGE

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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TABLE OF CONTENTS

Abstract ii
Abstract in Arabic iii
Approval Page iv
Declaration v
Copyright vi
Acknowledgements vii
Table of Contents viii
List of Figures xiii
List of Tables xv
List of Abbreviations xviii

CHAPTER ONE: INTRODUCTION 1
1.1 Background of The Study 1
1.2 Research Gap 2
1.3 Problem Statement 6
1.4 Research Philosophy 7
1.5 Research Objectives 10
1.6 Research Scope 10
1.7 Research Hypotheses and Proposed Model 10
1.8 Significance of The Study 12
1.9 Definitions of Terms 13
1.9.1 Manufacturing 13
1.9.2 Manufacturing Industries 13
1.9.3 Maintenance 13
1.9.4 Total Productive Maintenance 14
1.9.5 Lean Manufacturing 14
1.9.6 Manufacturing Performance 14
1.10 Organisation of Thesis 15

CHAPTER TWO: LITERATURE REVIEW 17
2.1 Introduction 17
2.2 Manufacturing Industry 17
2.2.1 Introduction 17
2.2.2 Manufacturing Definition in the Modern Context 18
2.2.2.1 In Terms of Technology 18
2.2.2.2 In Terms of Economics 19
2.2.3 Manufacturing Industries 20
2.2.4 Indonesian Manufacturing Industry and Its Importances ... 22
2.2.5 The Distribution of Industrial Groups 24
2.2.6 Production Efficiency Level 25
2.2.7 The Role of the Indonesian Manufacturing Industries in Providing Employment 28
2.2.8 Medium and Large Companies in Indonesia 29
2.3 Maintenance and Total Productive Maintenance 32
2.3.1 Introduction 32

2.3.2 Maintenance Definition and Evolution …………………… 35
2.3.3 Total Productive Maintenance ……………………………. 39
2.3.4 Total Productive Maintenance Barriers and Enablers ……. 42
2.4 Lean Manufacturing ……………………………………….…... 42
2.4.1 Lean Manufacturing Barriers and Enablers ………………. 43
2.5 The Role of Total Productive Maintenance and Lean Manufacturing in Manufacturing Industries ………………………… 44
2.6 Implementation of TPM and Its Impact on Manufacturing Performance ……………………………………………….......... 46
2.7 The Role of TPM in Lean Manufacturing ………………………. 48
2.8 Lean Manufacturing and Its Impact on Manufacturing Performance ……………………………………………………… 50
2.9 Chapter Summary ………………………………………………. 50

CHAPTER THREE: RESEARCH METHODOLOGY ………………… 51
3.1 Introduction ……………………………………………………… 51
3.2 Research Design …………………………………………………. 52
3.3 Research Population …………………………………………….. 54
3.4 Respondent of the Study and the Sample Size ………………….. 54
3.4.1 Respondent ……………………………………………….. 54
3.4.2 Sample Size for PLS-SEM Method ………………………. 55
3.5 Instrumentation …………………………………………………….. 56
3.5.1 Enabler and Barrier Factors in TPM Implementation in Indonesia ……………………………………………………….. 58
3.5.2 Enabler and Barrier Factors in LM implementation in Indonesia ……………………………………………………….. 58
3.5.3 The TPM Pillars ………………………………………….. 59
3.5.4 The Selection of LM Tools ………………………………. 59
3.5.5 Manufacturing Performance ……………………………… 60
3.5.6 Content Detail and Validation ……………………………. 60
3.5.6.1 Questions Detail for Total Productive Maintenance Pillars (X_1) ………………………………………………… 60
3.5.6.2 Questions Detail for Lean Manufacturing Tools (X_2) ……………………………………………………… 62
3.5.6.3 Questions Detail for Manufacturing Performance (Y_1) ……………………………………………………… 64
3.6 Pilot Study …………………………………………………….. 65
3.7 Analysis of Pilot Data …………………………………………… 66
3.8 Data Collection Procedures ……………………………………… 66
3.9 Data Analysis Procedures ……………………………………….. 68
3.10 Cochran Test …………………………………………………… 68
3.11 The Structural Equation Modelling ……………………………. 71
3.11.1 Measurement Model (Outer Model) Evaluation ……….. 72
3.11.2 Structural Model (Inner Model) Evaluation ……………. 73
3.11.3 Goodness of Fit (Model Fit) ……………………………. 75
3.12 Chapter Summary ……………………………………………… 76

CHAPTER FOUR: DATA ANALYSIS AND RESULTS PRESENTATION …………………………………………………………… 78
Part One: Demographic Information of Respondent ……………. 78
4.1 Part One: Introduction …………………………………………… 78
4.2 Respondent Description …………………………………………. 78
Part Two: TPM and LM Implementation in Indonesian Manufacturing Industries …………………………………………… 81
4.3 Part Two: Introduction …………………………………………... 81
4.4 Variables Description and Current Condition …………………… 83
4.5 Enablers and Barriers in TPM Implementation …………………. 86
4.5.1 The Enablers of TPM Implementation …………………… 86
4.5.2 The Barriers of TPM Implementation ……………………. 88
4.6 Enablers and Barriers in LM Implementation …………………… 92
4.6.1 The Enablers of LM Implementation …………………… 92
4.6.2 The Barriers of LM Implementation ……………………. 95
4.7 Data Screening …………………………………………………….. 99
4.7.1 Data Screening: Pilot Study ……………………………… 99
4.7.2 Data screening: Main Data ………………………………. 100
4.8 Data Collection …………………………………………………… 100
4.8.1 Pilot Study ……………………………………………….... 100
4.8.1.1 Mean value determination for indicators construct 101
4.8.1.2 Validity and Reliability Tests for TPM Pillars Questionnaire ……………………………………………… 102
4.8.1.2.1 Validity Test of TPM Pillars Questionnaire 102
4.8.1.2.2 Reliability Test for TPM Pillars Questionnaires ………………………………………. 102
4.8.1.3 Validity and Reliability Tests for LM Tools Questionnaires ..……………………………………………….. 103
4.8.1.3.1 Validity test for LM tools questionnaire …… 103
4.8.1.3.2 Reliability test for LM tools questionnaire … 103
4.8.1.4 Validity and Reliability Tests of MP Questionnaires 104
4.8.1.5 Outer and Inner Models Analysis ………………… 105
4.8.2 Main Data Results ……………………………………….. 106
4.8.3 Main Data Analysis ……………………………………… 107
4.8.3.1 The Distribution of OEE Values …………………. 107
4.8.3.2 The Validity and Reliability Tests of Constructs …. 107
4.8.3.3 The Validity and Reliability Test of TPM Construct 108
4.8.3.4 The Validity and Reliability Test of LM Construct 112
4.8.3.5 The Validity and Reliability Test of MP Construct 114
4.9 Model Analysis ………………………………………………….. 116
4.9.1 Proposed Model Analysis ………………………………… 116
4.9.1.1 Measurement Model Evaluation (Outer Model) …. 117
4.9.1.2 Structural Model Evaluation (Inner Model) ………. 118
4.9.2 Revised Model Analysis …………………………………. 119
4.9.3 Model Fit Evaluation ……………………………………... 122
4.10 Hypotheses Testing …………………………………………….. 123
4.11 Chapter Summary ………………………………………………. 125

CHAPTER FIVE: DISCUSSION AND NOVELTY …………………….. 128
5.1 Introduction …………………………………………………… 128
5.2 The Profile of Respondent ……………………………………… 128
5.3 The Description of Research Variables ………………………….. 129
5.4 TPM Enablers and Barriers …………………………………… 133
5.4.1 TPM Enablers …………………………………………….. 133
5.4.1.1 Top Management Support and Involvement ………. 134
5.4.1.2 Clear Steps (Gradual) of Implementation Process 135
5.4.1.3 Clear Understanding of TPM's Benefits and the Targets ……………………………………………… 135
5.4.1.4 Managing Synergic Cooperation of Production and Maintenance ……………………………………......... 135
5.4.1.5 Integrating TPM with other programs (LM, TQM, Six Sigma, etc) ………………………………………….. 136
5.4.2 TPM Barriers ……………………………………………... 136
5.4.2.1 Lack of Top Management Commitment and Support ……………………………………………… 137
5.4.2.2 Lack of Employee Involvement …………………… 137
5.4.2.3 Lack of Training and Education …………………... 137
5.4.2.4 Lack of Clear Understanding of TPM ……………... 138
5.4.2.5 Resistance to Change ……………………………… 138
5.4.2.6 Lack of Organizational Communication …………... 139
5.4.2.7 Lack of supports system (IT, Learning center, etc.) 139
5.5 LM Enablers and Barriers …………………………………….. 139
5.5.1 LM Enablers …………………………………………… 139
5.5.1.1 Top Management Support and Involvement ………. 140
5.5.1.2 High Employee Involvement ……………………… 141
5.5.1.3 Managing Synergic Cooperation of Production and Maintenance ……………………………………………….. 141
5.5.1.4 Integrating with other programs (TPM, TQM, JIT) 142
5.5.2 LM Barriers ……………………………………………… 142
5.5.2.1 Lack of Top Management Commitment and Support ………………………………………………….. 142
5.5.2.2 Lack of Employee Involvement …………………… 143
5.5.2.3 Low OEE, High Rejection Rate and High Set-up …. 143
5.5.2.4 Lack of Organizational Communication …………... 144
5.5.2.5 Lack of Supports System (IT, Learning facility etc) 145
5.6 The Influence of TPM Pillars Implementation to Manufacturing Performance ……………………………………………………..... 145
5.7 The Influence of TPM Pillars Implementation on LM Tools …… 147
5.8 The Influence of LM Tools Implementation to Manufacturing Performance ……………………………………………………..... 148
5.9 The Influence of TPM Pillars, OEE, and LM Tools Implementation to Manufacturing Performance …………………….. 150
5.10 Novelty ………………………………………………………. 152

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS ……. 154
6.1 Conclusions ………………………………………………........ 154
6.2 Recommendations ……………………………………………….. 156

REFERENCES ………………………………………………………….. 158

APPENDICES …………………………………………………………… 168
APPENDIX 1. Research Questionnaire …………………………….. 169
APPENDIX 2. Data on Pilot Study …………………………………. 180
APPENDIX 3. Raw Data on TPM Pillars …………………………... 181
APPENDIX 4. Raw Data on LM Tools …………………………….. 186
APPENDIX 5. Raw Data on Manufacturing Performance …………. 191
APPENDIX 6. Data on TPM Pillars (For processing) ……………… 194
APPENDIX 7. Data on LM Tools (For processing) ………………... 197
APPENDIX 8. Data on Manufacturing Performance
(For processing) …………………………………………………... 200

LIST OF FIGURES

Figure 1.1	TPM and Lean Manufacturing tools (Ahuja, 2008)	7
Figure 1.2	The Hypothesized Model Proposed for TPM Pillars and LM Tools Implementation and Their Impact on MP in Indonesia	11
Figure 2.1	Manufacturing Process in Terms of Technology (Groover, 2010)	18
Figure 2.2	Manufacturing Process in Terms of Economics (Groover, 2010)	19
Figure 3.1	Research Flow Chart	53
Figure 4.1	Industrial Classification of the Respondents	79
Figure 4.2	Percentage of Respondent's Staff Number	79
Figure 4.3	Companies Operating Age and Lifespan	80
Figure 4.4	Company's TPM Implementation Span	81
Figure 4.5	Company's LM Implementation Span	81
Figure 4.6	TPM Enablers (sorted)	86
Figure 4.7	TPM Barriers (sorted)	89
Figure 4.8	LM Enablers (sorted)	92
Figure 4.9	LM Barriers (sorted)	96
Figure 4.10	CFA and SEM Model for Pilot Study	105
Figure 4.11	OEE Distribution	107
Figure 4.12	CFA of TPM indicators	108
Figure 4.13	The PLS Algorithm for the Modified 7 Pillars of TPM	110
Figure 4.14	PLS Algorithm for the Six Pillars of TPM	111
Figure 4.15	CFA for LM Construct	112
Figure 4.16	CFA for MP Construct	114
Figure 4.17	The Influence of TPM and LM to MP (Model #1)	117

Figure 4.18	The Influence of TPM and LM to MP (Final Model)	120
Figure 5.1	Lean Manufacturing Tools Relationship Model	148

LIST OF TABLES

Table 1.1	Sectorial Contribution in the Indonesia Economics year 1990-2017 (in percentage) (Statistical Center, 2018)	1
Table 1.2	Previous Research on TPM, LM, and Manufacturing Performance	3
Table 2.1	Specific industries in the primary, secondary, and tertiary categories by ISIC (Groove, 2010)	21
Table 2.2	The Contributions of Each Industrial Group to GDP (Per cent) (Lakip, 2016)	26
Table 2.3	The Efficiency (output/input) of Large and Medium Manufacturing Companies (2010-2014)	27
Table 2.4	The Classification of Company Category Based on the Size of the Staff Headcount According to DTI, UK (Source: https://www.gov.uk/government/organisations/dti)	30
Table 2.5	The Classification of Company Category Based on the Size of the Staff Headcount According to European Commission, EU (Source: http://ec.europa.eu/growth/smes/sme-definition)	31
Table 2.6	The Classification of Company Category Based on the Size of the Staff Headcount According to Small Business Act (SBA) 1953, USA (Source: https://www.sba.gov/about-sba)	31
Table 2.7	Illustration of Maintenance vs. Repair/Replace	35
Table 2.8	Maintenance Strategies, Technique Needed and Cost per Horse Power/year (Fitch, 1992)	39
Table 2.9	Brief Summary of Eight Pillars (Ahuja, 2008; Pandey, 2016)	41
Table 3.1	Critical Limit/Border Value for Measurement Model Evaluation	74
Table 3.2	Critical Limit/Border value for Structural Model Evaluation (Chin, 1998; Chin, 2010; Hair, 2011; Hair, 2012; Cohen 1988; Ghozali, 2015).	74
Table 3.3	Goodness of Fit Criteria (Model Fit) (Henseler (2016; 2017); Djikstra (2015); Ghozali (2015) and Byrne (2008)	75

Table 4.1	The TPM Pillars Mean, Standard Deviation, and Mode Values	84
Table 4.2	The LM Tools Mean, Standard Deviation, and Mode Values	84
Table 4.3	The Manufacturing Performance Mean, Standard Deviation, and Mode Values of the Research	85
Table 4.4	The Cochran Test Result for Five Enablers of TPM	88
Table 4.5	The Cochran Test Result for The Eight Barriers of TPM	90
Table 4.6	The Cochran Test Result for Seven Barriers of TPM	91
Table 4.7	The Cochran Test Result for Six Enablers of LM	94
Table 4.8	The Cochran Test Result for Five Enablers of LM	94
Table 4.9	The Cochran Test Result for Four Enablers of LM	95
Table 4.10	The Cochran Test Result for Eight Barriers of LM	97
Table 4.11	The Cochran Test Result for Seven Barriers of LM	98
Table 4.12	The Cochran Test Result for Five Barriers of LM	98
Table 4.13	Pilot Study Data Collection Result (n = 30)	101
Table 4.14	The List of Less Valid Questions According to their Cut-Off Values	102
Table 4.15	The Reliability Test for TPM Pillars	102
Table 4.16	The Reliability Test for LM tools	103
Table 4.17	The Reliability Test for MP Indicators	104
Table 4.18	Model Reliability and Validity	105
Table 4.19	Construct Reliability and Validity for TPM Pillars	112
Table 4.20	Construct Reliability and validity for LM tools	114
Table 4.21	Construct Reliability and Validity for MP	115
Table 4.22	Outer Loadings #1 (Bootstrapping Analysis)	115
Table 4.23	Outer Loadings #2 (Bootstrapping Analysis)	116
Table 4.24	Construct Reliability and Validity Values	118

Table 4.25	R^2 Values for the Inner Model	119
Table 4.26	R^2 Calculation Results	121
Table 4.27	The f^2 Calculation Results	121
Table 4.28	The Test of Model Fit Results	122
Table 4.29	Signifancy Test for TPM, LM and MP	123
Table 4.30	Indirect Effect of TPM to MP through LM	124
Table 5.1	The Percentage of Industrial Companies with Proper TPM Pillars Implementation	129
Table 5.2	The Percentage of Industrial Companies with Proper LM Tools Implementation	131
Table 5.3	The Effect of TPM Pillars and LM Tools Implementation on Manufacturing Performance of Indonesia Manufacturing Industry	133

LIST OF ABBREVIATIONS

CBM	Condition-Based Maintenance
CI	Continuous Improvement
CM	Corrective Maintenance
CFA	Confirmatory Factors Analysis
EPS	Eight Pillars Strategy
FMEA	Failure Mode and Effect Analysis
FMECA	Failure Mode Effect and Criticality Analysis
FTA	Fault Tree Analysis
HAZOP	Hazard and Operability
LM	Lean Manufacturing
MP	Maintenance Prevention
MP	Manufacturing Performance
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
OMF	Optimising Maintenance Function
PdM	Predictive Maintenance
PHA	Physical Hazard Analysis
PM	Preventive Maintenance
Pro-M	Proactive Maintenance
RCM	Reliability Centred Maintenance
SEM	Structural Equation Modelling
TBM	Time-Based Maintenance
TPM	Total Productive Maintenance
TQM	Total Quality Management
VSM	Value Stream Mapping

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The sector of manufacturing industry was known to be very influential in the structural transformation process of Indonesian economics. Since 1990, the influence has surpassed the agricultural sector in forming the national Gross Domestic Product (GDP), despite of the decreasing contribution of the agricultural sector each year. On the other hand, the manufacturing sector has been consistently becoming more influential. In 2001, the sector contributed to approximately 30.1% of Indonesia's GDP. In the following years, its contribution went down several times, with the lowest in 2013 at only 20.1% of the total GDP. The details on the development of the sectorial contribution are presented in Table 1.1.

Table 1.1: Sectorial Contribution in the Indonesia Economics year 1990-2017 (in percentage) (Ayu, 2010; Bappenas, 2010; Perindustrian, 2015, 2018; Statistical Center, 2018)

Year	Agricultural	Manufacturing (include oil and gas)	Others
1990	19.4	20.7	59.9
1995	17.1	24.1	58.8
2001	15.6	30.1	54.3
2009	14.1	27.2	61.5
2010	14.4	23.2	62.4
2011	13.9	21.8	64.3
2012	14.1	21.5	64.4
2013	13.8	21.0	65.2
2014	13.7	21.0	65.3
2015	13.7	22.0	64.3
2016	13.3	21.1	65.6
2017	13.1	21.2	65.7

From 2011-2017, the performance of process industry (manufacturing) appeared to be stagnant at 21-22% of the GDP with a total value of IDR 2,418.89 trillion in the year 2015, IDR 2,545.20 in the year 2016 and IDR 2,739.42 trillion in the year 2017. Although it may have seemed to be stagnant, nominally it went up about IDR 534.89 trillion (28.39%), IDR 661.20 trillion (35.09%) and IDR 855.4 trillion (45.40%) compare to 2014's GDP with the total GDP was IDR 1,884 trillion (Kementerian Perindustrian Republik Indonesia, 2017). In the future, the Indonesian government through UU No.17 2007 concerning the National Long-Term Development Plans (RPJPN) is planning to make Indonesia a new industrial country where its industrial sector become the main source of income with a yearly growth of 8.6% and 40% GDP contribution in 2025 (Kementerian Perindustrian Republik Indonesia, 2017).

It is thus obvious that Indonesia's manufacturing sector play an important role in Indonesian economics. But unfortunately, the Indonesia's manufacturing performance was not good enough. They were observed to still having low Overall Equipment Effectiveness (OEE), low reliability, and high breakdown (Asgara & Hartono, 2014; Puspitasari & Bagas, 2015; Triwardani et al., 2012). Very limited companies have been implementing Lean Manufacturing (LM) strategies such as Just-in-Time (JIT), Total Quality Management (TQM), and Total Productive Maintenance (TPM). There is a need to implement these strategies in the Indonesian manufacturing industries to improve the performance of the companies on quote.

1.2 RESEARCH GAP

Several researchers like (Ahuja & Khamba, 2008a; Belekoukias et al, 2014; Pham et al., 2008) have found that many companies pursued either TPM or LM to improve their business strategy. However, it was observed that most of the implementation of these initiatives was done separately. The integration of TPM with LM should form a comprehensive and consistent set of manufacturing practices directed towards performance improvement. Without having a TPM as complementary, an LM initiative would be strenuous and gruelling (Ahuja & Khamba, 2008; Bakri et al., 2012). In other words, without a well-run TPM programme, a non-lean company would have difficulties converting itself into lean companies. Managing the plant will be also more effective if those initiatives are integrated as a single set of manufacturing practice. Both TPM and LM initiatives have their own strength and have a significant impact in supporting the others (Pham et al., 2008)

So far, the extensive research focusing on this topic are very limited, if any. There is a need for further research to comprehensively integrate these two initiatives and to evaluate their impact towards manufacturing performance (MP). To provide a solid foundation for this research, a literature-study on 21 major recent journals with the subject of TPM, LM and manufacturing/organization performance has been carried out. Table 1.2 provides the details of the study.

Table 1.2: Previous Researches on TPM, LM, and Manufacturing Performance

Authors	**Result/Conclusion**							
	TPM Deep Inves-tigation	LM Deep Inves-tigation	OEE Calculation	Manu-factu-ring Performance	TPM Effect to LM	TPM Effect to Manufacturing Perfor-mance	LM Effect on Manufacturing Perfor-mance	SEM for TPM. LM and Manufacturing Perfor-mance
1. (Nawanir et al, 2016)	NO	YES	NO	YES	NO	NO	YES	YES
2. (Wickramasinghe & Perera, 2016)	YES	NO	NO	YES	NO	YES	NO	NO
3. (Filho et al., 2016)	NO	YES	NO	YES	NO	NO	YES	YES

Authors	Result/Conclusion							
	TPM Deep Inves-tigation	LM Deep Inves-tigation	OEE Calculation	Manu-factu-ring Performance	TPM Effect to LM	TPM Effect to Manufacturing Perfor-mance	LM Effect on Manufacturing Perfor-mance	SEM for TPM. LM and Manufacturing Perfor-mance
4. (Upadhye et al., 2016)	NO	YES	NO	NO	NO	NO	NO	NO
5. (Srinivasa & Niraj, 2016)	NO	YES	NO	YES	NO	NO	YES	NO
6. (Tang et al., 2016)	NO	YES	NO	YES	NO	YES	NO	NO
7. Thanki et al. (2016)	YES	YES	NO	NO	NO	NO	NO	NO
8. Tomar & Bhuneriya (2016)	NO	NO	YES	NO	NO	NO	NO	NO
9. Mishra & Aarif (2016)	NO	YES	NO	NO	NO	NO	YES	NO
10. (Zahraee, 2016)	NO	YES	NO	NO	NO	NO	YES	NO
11. Belekoukias et al. (2014)	NO	YES	NO	YES	NO	YES	YES	YES
12. Rahman et al. (2013)	NO	YES	NO	NO	NO	NO	YES	NO
13. Bakri et al. (2012)	YES	YES	NO	NO	YES	YES	YES	NO
14. Ahmad et al. (2012)	NO	NO	NO	YES	NO	YES	NO	NO
15. Hashim et al. (2012)	YES	NO	NO	YES	NO	YES	NO	YES
16. Anvari et al. (2011)	NO	YES	NO	NO	NO	NO	NO	NO
17. Teeravaraprug et al. (2011)	YES	YES	NO	NO	YES	NO	NO	NO
18.Dang Minh (2011)	YES	NO	NO	NO	YES	YES	NO	NO
19. Stamm et al. (2009)	YES	YES	NO	NO	NO	NO	NO	NO

Authors	**Result/Conclusion**							
	TPM Deep Inves-tigation	LM Deep Inves-tigation	OEE Calcul ation	Manu-factu-ring Perform ance	TPM Effect to LM	TPM Effect to Manufac turing Perfor-mance	LM Effect on Manufac turing Perfor-mance	SEM for TPM. LM and Manufac turing Perfor-mance
20. Ahuja & Khamba (2008)	YES	NO	YES	YES	NO	YES	NO	NO
21. Shah & Ward (2007)	NO	YES	NO	YES	NO	NO	YES	NO
This research	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**

In performing the analysis of correlation between TPM and LM, many researchers treated TPM and LM as an observed instead of unobserved (latent) variable. Only limited researchers treated TPM, LM and MP as unobserved variables, such as Belekoukias et al. (2014), Hashim et al. (2012), and Shah & Ward (2007). In this research, the TPM and LM variables were treated as unobserved (latent) variables and were measured through their indicators. Structural Equation Modeling (SEM) was considered to be the appropriate method to perform the analyses (confirmatory, measurement and model fit). It can be inferred from this chapter that though there is a vast amount of literature on TPM, LM and their concepts, what is available on the aspects affecting the implementation of TPM and LM in industries is limited. There is big scope for carrying out additional research on this issue using SEM. It is also seen that statistical validation of the model developed in SEM regarding TPM and LM implementation and their impact on MP is yet to be carried out by those researchers, and hence there is an ample opportunity for further research.

1.3 PROBLEM STATEMENT

Only a very limited number of companies in Indonesia have been implementing TPM and LM properly. Many managers still consider TPM implementation as an additional costs or expenditures. So, in most cases, maintenance is still reactive in nature. Results from previous research show that many companies within the manufacturing industries in Indonesia have a machine/tool performance score below the Japan Institute of Plant Maintenance (JIPM) world class standard with minimum OEE at 85%. A study from Asgara & Hartono (2014) found that the OEE value of an overhead crane 003/0HC/BRB machine was still below the expected standard which is set at 71.63%. Another study from Triwardani et al. (2012) also found that the average effectiveness level of Dual Filters DD07 machine during their research was 26.22% with an average availability value of 69.88%, performance 45.37%, and quality 89.06%. Puspitasari & Bagas (2015) found the OEE value of Banbury Mixer 270 L machine to be 71.07%.

Similar to TPM, LM practices for manufacturing companies in most developing countries, especially Indonesia, are still lagging behind and below those of world-class performance. They are still struggling to overcome the implementation’s barriers, and they also have been implementing LM separately from TPM. This separation resulted in a requirement of a large-scale resources, not to mention the associated problems of running contending project in the company.

Achieving the operational excellence, generating the models of LM and TPM implementation, and resulting the effect of both on MP, are of great importance to be created. By providing the current condition of TPM and LM practices, combined with the reference model of a relationship between TPM, LM, and MP, an important archive for academic and practitioners (industries) can be possibly provided.