AUTONOMOUS MAINTENANCE DECISION MODEL FOR LATHE MACHINE USING FUZZY ANALYTICAL HIERARCHY PROCESS (AHP) METHOD

© This item is protected by original copyright

AHMADI HAMDAN BIN MUSMAN

UNIVERSITI MALAYSIA PERLIS

2015

Autonomous Maintenance Decision Model for Lathe Machine Using Fuzzy Analytical Hierarchy Process (AHP) Method

by

AHMADI HAMDAN BIN MUSMAN

(1432421144)

A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science (Manufacturing Systems Engineering)

School of Manufacturing Engineering

UNIVERSITI MALAYSIA PERLIS

2015

© This item is protected by original copyright

UNIVERSITI MALAYSIA PERLIS

DECLARATION OF THESIS

Author's full name	:	AHMADI HAMDAN BIN MUSMAN
Date of birth	:	AUGUST 25, 1982
Title	:	AUTONOMOUS MAINTENANCE DECISION MODEL FOR LATHE MACHINE USING FUZZY ANALYTICAL HIERARCHY PROCESS (AHP) METHOD
Academic Session	:	2015

I hereby declare that the thesis becomes the property of Universiti Malaysia Perlis (UniMAP) and to be placed at the library of UniMAP. This thesis is classified as :

☐ **CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐ **RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
☐ **OPEN ACCESS**	I agree that my thesis is to be made immediately available as hard copy or on-line open access (full text)

I, the author, give permission to the UniMAP to reproduce this thesis in whole or in part for the purpose of research or academic exchange only (except during a period of _____ years, if so requested above).

Certified by:

_____ **SIGNATURE**

820825-08-5461

(NEW IC NO. / PASSPORT NO.)

Date :_____

_____ **SIGNATURE OF SUPERVISOR**

DR. ROSMAINI BIN AHMAD

NAME OF SUPERVISOR

Date : _____

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

© This item is protected by original copyright

ACKNOWLEDGEMENT

In the Name of Allah, the Most Gracious and the Most Merciful.

Alhamdulillah. All praises to Allah, for His permission this research has reached its completion. I would like to express my deepest gratitude to my supervisor Dr. Rosmaini bin Ahmad for invaluable guidance and support throughout my Master journey. I am most fortunate to have the advice and assistance of a talented person whom knowledge has enhanced this study in so many ways.

Also, I would like to express my sincere gratitude to all lecturers that involve direct or indirect for giving me information and idea to complete my research. It is also pleasure to thank Ministry of Education for their sponsorship.

Last but not least, I am forever indebted to my family who has always been understanding and supporting throughout my study. My special thanks to my beloved wife Nurul Nazihah Hawari for his patience and to my precious sons Ahmad Zhafran and Ahmad Zharif. Not to forget my special thanks to my adored parents, Hj. Musman Isnin and Hjh. Mariam Abdul Aziz, as well as my postgraduate friends for constant support and prayer.

© This item is protected by original copyright

TABLE OF CONTENTS

		PAGE
DECLARATION SHEET		i
ACKNOWLEDGEMENT		ii
TABLE OF CONTENTS		iii
LIST OF TABLES		vii
LIST OF FIGURES		xi
ABSTRAK		xii
ABSTRACT		xiii
CHAPTER 1 INTRODUCTION		1
1.1	Introduction	1
1.2	Background of Research	1
1.3	Problem Statement	2
1.4	Objectives of the Study	3
1.5	Scope and Limitation	4
1.6	Significant of the Study	4
1.7	Thesis Outline	5
CHAPTER 2 LITERATURE REVIEW		6
2.1	Introduction	6
2.2	Total Productive Maintenance (TPM)	6
	2.2.1 Autonomous Maintenance	8

© This item is protected by original copyright

2.2.2 Technical Issue of Autonomous Maintenance 9

2.3 Multi Criteria Decision Making Methods 11

2.4 Maintenance Decision Model Using Fuzzy Analytical Hierarchy Process 13

2.5 Literature Findings 15

CHAPTER 3 METHODOLOGY 17

3.1 Introduction 17

3.2 Autonomous Maintenance Decision Model 17

3.2.1 Hierarchy Structuring of the Problem 18

3.2.2 Criteria Weighting 20

3.2.3 Alternative Weighting 25

3.2.4 Final Score of the Alternatives 26

3.2.5 Critical Component Identification 26

3.3 Summary 27

CHAPTER 4 MODEL VALIDATION AND DISCUSSION 28

4.1 Introduction 28

4.2 Case Study: Lathe Machine 28

4.3 Lathe Machine Sections 29

4.4 Hierarchy Structuring of the Problem 32

4.4.1 Goal Identification 33

4.4.2 Criteria Selection 33

© This item is protected by original copyright

4.4.3 Alternative Identification 34

4.5 Model Validation On the Headstock Section 36

4.5.1 Hierarchy Structure 36

4.5.2 Criteria Weighting 37

4.5.3 Alternative Weighting 39

4.5.4 Final Score of the Alternatives 44

4.5.5 Critical Components Identification 45

4.6 Model Validation On the Carriage Section 47

4.6.1 Hierarchy Structure 47

4.6.2 Criteria Weighting 48

4.6.3 Alternative Weighting 50

4.6.4 Final Score of the Alternatives 55

4.6.5 Critical Components Identification 56

4.7 Model Validation On the Tailstock Section 57

4.7.1 Hierarchy Structure 57

4.7.2 Criteria Weighting 57

4.7.3 Alternative Weighting 59

4.7.4 Final Score of the Alternatives 62

4.7.5 Critical Components Identification 63

4.8 Results Discussion 64

4.8.1 Discussion 1: Critical Components On Lathe Machine 64

4.8.2 Discussion 2: Suggestion For The Remedy To Sustain The Lathe Condition 66

4.9 Summary 67

© This item is protected by original copyright

CHAPTER 5 CONCLUSION 68

5.1 Introduction 68

5.2 Research Summary 68

5.3 Research Finding 69

5.4 Research Achievement 70

5.5 Research Contribution 71

5.6 Future Research Recommendation 73

REFERENCES 74

APPENDICES 78

Appendix A Pairwise Comparison Matrices on Headstock 78

Appendix B Pairwise Comparison Matrices on Carriage 82

Appendix C Pairwise Comparison Matrices on Tailstock 86

LIST OF PUBLICATION 90

© This item is protected by original copyright

LIST OF TABLES

NO.		PAGE
2.1	Advantages and limitations of the fuzzy AHP	14
3.1	Linguistic terms and the triangular fuzzy number	21
3.2	Random consistency index (RI)	24
3.3	Critical component and type of maintenance activity	27
4.1	Type of dirtiness	33
4.2	Type of looseness	34
4.3	Type of weariness	34
4.4	Components selection for analysis	35
4.5	Averaged fuzzy pairwise comparison	37
4.6	Averaged pairwise comparison of the criteria	38
4.7	Consistency ratio (CR) of the criteria judgement matrix	38
4.8	Geometric mean and relative fuzzy weight of criteria	39
4.9	Averaged and normalized relative weights of criteria in a headstock	39
4.10	Averaged fuzzy pairwise comparison with respect to Dirty	40
4.11	Averaged fuzzy pairwise comparison with respect to Loose	40
4.12	Averaged fuzzy pairwise comparison with respect to Wear	40
4.13	Averaged pairwise comparison of the alternatives with respect to Dirty	41
4.14	Averaged pairwise comparison of the alternatives with respect to Loose	41
4.15	Averaged pairwise comparison of the alternatives with respect to Wear	41
4.16	Consistency Ratio of alternative judgement matrix with respect to Dirty	42

© This item is protected by original copyright

4.17	Consistency Ratio of alternative judgement matrix with respect to Loose	42
4.18	Consistency Ratio of alternative judgement matrix with respect to Wear	42
4.19	Geometric mean and relative fuzzy weight of alternatives with respect to Dirty	43
4.20	Geometric mean and relative fuzzy weight of alternatives with respect to Loose	43
4.21	Geometric mean and relative fuzzy weight of alternatives with respect to Wear	43
4.22	Averaged and normalized relative weights of alternatives with respect to Dirty	44
4.23	Averaged and normalized relative weights of alternatives with respect to Loose	44
4.24	Averaged and normalized relative weights of alternatives with respect to Wear	44
4.25	The final score of the alternatives in a headstock section	45
4.26	Averaged fuzzy pairwise comparison	48
4.27	Averaged pairwise comparison of the criteria	49
4.28	Consistency ratio (CR) of the criteria judgement matrix	49
4.29	Geometric mean and relative fuzzy weight of criteria	49
4.30	Averaged and normalized relative weights of criteria in a carriage	50
4.31	Averaged fuzzy pairwise comparison with respect to Dirty	51
4.32	Averaged fuzzy pairwise comparison with respect to Loose	51
4.33	Averaged fuzzy pairwise comparison with respect to Wear	51
4.34	Averaged pairwise comparison of the alternatives with respect to Dirty	52
4.35	Averaged pairwise comparison of the alternatives with respect to Loose	52
4.36	Averaged pairwise comparison of the alternatives with respect to Wear	52

© This item is protected by original copyright

4.37	The CR of alternative judgement matrix with respect to Dirty	52
4.38	The CR of alternative judgement matrix with respect to Loose	53
4.39	The CR of alternative judgement matrix with respect to Wear	53
4.40	Geometric mean and relative fuzzy weight of alternatives with respect to Dirty	53
4.41	Geometric mean and relative fuzzy weight of alternatives with respect to Loose	54
4.42	Geometric mean and relative fuzzy weight of alternatives with respect to Wear	54
4.43	Averaged and normalized relative weights of alternatives with respect to Dirty	54
4.44	Averaged and normalized relative weights of alternatives with respect to Loose	55
4.45	Averaged and normalized relative weights of alternatives with respect to Wear	55
4.46	The final score of the alternatives in a carriage section	55
4.47	Averaged fuzzy pairwise comparison	58
4.48	Averaged pairwise comparison of the criteria	58
4.49	Consistency ratio (CR) of the criteria judgement matrix	58
4.50	Averaged and normalized relative weights of criteria in a tailstock	59
4.51	Averaged fuzzy pairwise comparison with respect to Dirty	60
4.52	Averaged fuzzy pairwise comparison with respect to Loose	60
4.53	Averaged fuzzy pairwise comparison with respect to Wear	60
4.54	The CR results for alternative judgement matrices with respect to dirty, loose and wear	61
4.55	Averaged and normalized relative weights of alternatives with respect to Dirty	61
4.56	Averaged and normalized relative weights of alternatives with respect to Loose	62

© This item is protected by original copyright

4.57 Averaged and normalized relative weights of alternatives with respect to Wear 62

4.58 The final score of the alternatives in a tailstock section 62

4.59 Critical components on lathe machine and its conditions 64

© This item is protected by original copyright

LIST OF FIGURES

NO.		PAGE
2.1	Total Productive Maintenance (TPM) framework	7
3.1	Autonomous maintenance decision model	18
3.2	Hierarchy structure of the problem	20
4.1	WIN HO Model 430X760 lathe machine	29
4.2	Lathe section classification	30
4.3	Headstock section	30
4.4	Carriage section	31
4.5	Tailstock section	32
4.6	Hierarchy structure of lathe machine	35
4.7	Hierarchy structure in headstock section	36
4.8	Hierarchy structure in carriage section	47
4.9	Hierarchy structure in tailstock section	57
4.10	Oiling points for lead screw and spindle	65
4.11	'Labelling' showing the instructions for lubrication	67

© This item is protected by original copyright

Model Keputusan Penyelenggaraan Autonomi untuk Mesin Larik Menggunakan Teknik Fuzzy Proses Hirarki Analisis (PHA)

ABSTRAK

Kemerosotan pada mesin pengeluaran boleh menjurus kepada kos pengeluaran yang tinggi. Salah satu strategi penyelenggaraan pencegahan bagi mengurangkan kemerosotan mesin ialah penyelenggaraan autonomi. Tujuan penyelenggaraan autonomi adalah untuk mencapai satu tahap kebersihan yang tinggi, pelinciran yang sempurna dan pengetatan yang sesuai pada mesin. Namun begitu, amalan penyelenggaraan autonomi sedia ada hanya meningkatkan kos dan masa penyelenggaraan yang diperlukan. Oleh itu, kajian ini menyarankan model keputusan penyelenggaraan autonomi menggunakan teknik fuzzy "Proses Hirarki Analisis" (PHA) untuk mengenalpasti komponen kritikal dan menentukan aktiviti penyelenggaraan autonomi yang tepat. Satu kajian kes pada mesin larik digunakan untuk mengesahkan model. Data kajian dikumpul melalui sesi temubual secara individu bersama juruteknik di makmal mesin di Universiti Malaysia Perlis. Dalam kajian ini, fuzzy PHA diaplikasikan menggunakan data pembezaan pasangan untuk pengesahan komponen kritikal. Hasil dapatan kajian menunjukkan bahawa terdapat lapan komponen kritikal dari mesin larik yang telah dikenalpasti. Dengan maklumat ini, model ini membantu dalam pengurangan kos dan masa penyelenggaraan dengan mengenal pasti komponen yang betul untuk penyenggaraan dan juga menentukan aktiviti penyelenggaraan yang betul untuk dilaksanakan. Oleh itu, kajian ini telah menerangkan secara teori dan praktikal tentang pembangunan model keputusan penyelenggaraan autonomi.

© This item is protected by original copyright

Autonomous Maintenance Decision Model for Lathe Machine Using Fuzzy Analytical Hierarchy Process (AHP) Method

ABSTRACT

Deterioration on production machine may lead to high production costs. One of the preventive maintenance strategies to reduce deterioration of machine is Autonomous Maintenance (AM). The aim of autonomous maintenance is to achieve a high degree of cleanliness, excellent lubrication and proper fastening on the machine. However, the conventional AM practice, the process of initial cleaning might increase the maintenance cost and the time required. Therefore, to make this process more effective and efficient, this study proposes an AM decision model using fuzzy Analytical Hierarchy Process (AHP) method to identify the critical components and to determine the right AM activities. A case study of a lathe machine is used to validate the model. The data were collected through personnel interview with technicians at machine shop laboratory in UniMAP. In this study, fuzzy AHP is carried out using pairwise comparison data to verify the critical components. Finding of the analysis reveals that there are eight critical components of the lathe machine that have been identified. By having this information, the model does help in minimizing the maintenance costs and time by identifying the right component for maintenance and so to determine the right maintenance activities to be carried out. Thus, this study has provide theoretical and practical inferences about the development of AM decision model.

© This item is protected by original copyright

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter encompasses six sections; the background of research, the problem statement, the objectives of the study, the scope and limitation, significant of the study, and thesis outline. Research background section gives overview about research content and focus. The problem statement section discusses the problems that occurred in the autonomous maintenance practices. Later, the objectives of the study is presented followed by the scopes and limitation. Next is significant of the study and thesis outline section ends this chapter.

© This item is protected by original copyright

1.2 Background of Research

Nowadays, the utilization of production machines do give a big impact to manufacturing industries in producing the variable shapes through processes such as threading, boring, external grooving, shearing, or other forms of deformation. Production machines employ some sort of tool that does the cutting and shaping or machining materials. Examples of production machines are lathe machine, milling machine, vertical band saw, grinding machine, drilling machine, CNC machine, belt and disc sanders, and many others.

Most production machines are subjected to deterioration with usage and age. Such machine deterioration may lead to higher production costs, lower product quality and the increased possibility of breakdown (Wang and Hwang, 2004). Therefore, a well-planned maintenance program is important to reduce costly breakdowns (Dohi et al., 2001). Generally, maintenance can be applied based on preventive maintenance. Preventive maintenance program involves the maintenance activities such as preventive repair and preventive replacement that performed before the machine breakdown (Gertsbakh, 1977 and Lofsten, 1999). Preventive maintenance contributes to reducing costs, minimizing machine downtime, increasing productivity and improving quality (Usher et al., 1998).

© This item is protected by original copyright

Autonomous Maintenance (AM) is a maintenance philosophy which has machine operators personally conducting maintenance activities, including cleaning, lubricating, tightening, inspection and even perform simple countermeasure. Such autonomous maintenance activities prevent forced deterioration of machine. For instance, untighten bolt or nut on a component/part may cause a vibration problem to the machine. The problem can be reduced through periodically tightening activity. The aim of autonomous maintenance is to achieve a high degree of cleanliness, excellent lubrication and proper fastening to reduce machine breakdown and maintenance cost.

1.3 Problem Statement

Most of the industries perform the Autonomous Maintenance (AM) process under the framework of Total Productive Maintenance (TPM). They accomplish the autonomous maintenance based on the general process of AM practice with conducting

initial cleaning as a first step. Through this cleaning activity, any problem with the machine or unsatisfactory conditions on component will be revealed.

However, it is found that in the conventional AM practice, the process of initial cleaning might increase the maintenance cost and the time required. In addition, this conventional procedures for AM practice is considered as less effective because it did not provide detailed information on how AM practice should be applied and implemented (Min et al., 2011).

In autonomous maintenance, it is vital to select the correct component for maintenance activity, in order to reduce the maintenance costs. However, there are very few of research discusses on this issue. Thus, this research is motivated by the fact that a new method in critical component selection is needed.

© This item is protected by original copyright

1.4 Objectives of the Study

The main research objective of this study is to develop the autonomous maintenance decision model for production machine equipment. The main part of the model is the application of Fuzzy Analytical Hierarchy Process (AHP) to analyze the data using pairwise comparison. The developed model will help maintenance engineering department in identifying the critical components towards autonomous maintenance program development. The specific objectives of this research are as follows:

i. To identify the suitable method to develop the autonomous maintenance decision model for critical component selection purpose.

ii. To develop an autonomous maintenance decision model of production machine using Fuzzy Analytical Hierarchy Process approach.
iii. To validate the proposed autonomous maintenance decision model using a case study of a lathe machine.

1.5 Scope and Limitation

This study focuses on developing a decision model of autonomous maintenance for critical component identification purpose. The scope and limitation of this study are as follows:

i. The model is developed by using Fuzzy Analytical Hierarchy Process method.
ii. The model is validated using a lathe machine as a case study of production machine.

© This item is protected by original copyright

1.6 Significant of the Study

This study develops a decision model of autonomous maintenance for lathe machine. In developing the model, the significant contributions made by this study are outlined as follow. In term of theory and model development, the main part of the model is the application of Fuzzy Analytical Hierarchy Process in developing an autonomous maintenance decision model to help the technicians in decision making to seek the critical component to be prioritized in maintenance activity.

In terms of practicality, an autonomous maintenance decision model using fuzzy AHP approach has been implemented at a lathe machine at UniMAP. Prioritizing

components for maintenance activities due to the limited resources is necessary and autonomous maintenance using fuzzy AHP approach is the first step toward a systematic maintenance trend. The approach presented in this study gives a possible and practical solution to maintenance decision making problems in selecting critical components for maintenance activities. Overcoming the conventional AHP shortcomings, this approach systematically formulates expert's knowledge about machines prioritizing to efficiently allocate available resources.

© This item is protected by original copyright

1.7 Thesis Outline

Chapter 2 discusses the key issues in autonomous maintenance and provides an overview of past autonomous maintenance applications. This chapter also presents an overview of the literatures on Fuzzy Analytical Hierarchy Process (AHP). Some classifications of Fuzzy Analytical Hierarchy Process applications are discussed.

Chapter 3 clarifies the research method employed in this study in order to achieve research objectives. This chapter explains the fuzzy AHP method in detail. Fuzzy AHP method is the core in development of AM decision model.

Chapter 4 describes the validation of AM decision model based on application in lathe machine as a case study. This chapter also include a section for discussion on model results and analysis.

Chapter 5 ended this dissertation as a conclusion chapter. It summarizes the research findings, discuss its contributions and how further work might best be directed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature in the topic of autonomous maintenance. The first section discusses the previous studies of the autonomous maintenance in the context of Total Productive Maintenance (TPM) program. Next, various multi criteria decision making methods for critical component selection in production machine are reviewed. Later, the advantages and limitations of multi criteria decision making methods are summarized. The final section concludes the findings from literature review.

© This item is protected by original copyright

2.2 Total Productive Maintenance (TPM)

Maintenance could be defined as a set of activities or tasks used to restore an item to a state in which it can perform its designated functions (Willmott and McCarthy, 2001). One of the maintenance practices that can be utilized is the Total Productive Maintenance (TPM). TPM is a maintenance framework which developed for improving productivity by making processes more reliable and less wasteful without interfering with the daily process. Figure 2.1 summaries the overall elements in the TPM framework.

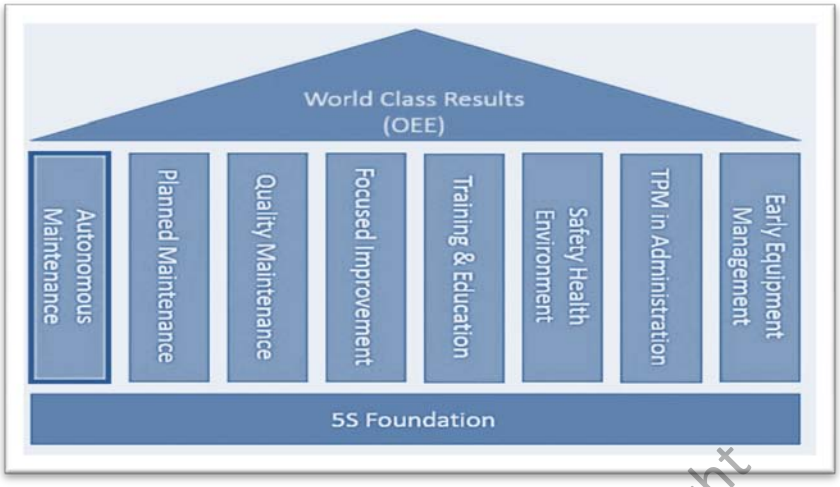

Figure 2.1: Total Productive Maintenance (TPM) Framework (Nakajima, 1989)

© This item is protected by original copyright

Figure 2.1 shows that TPM has a single goal at the highest level; which is to improve Overall Equipment Effectiveness (OEE) by reducing performance loss and increasing machine availability. OEE is used as a tool to know the current state of machine by measuring its effectiveness. In the TPM framework, Nakajima (1989) has identified six major losses which can affect the machine availability, performance efficiency and quality rate of products. The framework emphasizes that a stable 5S process is the foundation on which the entire system is built to achieve the above goals. The framework also shows the eight pillars or tools that are necessary to achieve the goals once a 5S process has been achieved. Autonomous Maintenance is one of the pillars and is illustrated with the 'house' shown in Figure 2.1.

2.2.1 Autonomous Maintenance

Autonomous maintenance (AM) is known as *Jitshu-Hosen* in Japanese, is a maintenance philosophy which emphasizes on the 'man-machine' relationship in performing three simple activities; cleaning, lubricating and tightening. This relationship refers to the corporation system between maintenance personnel and machine operators towards eliminating the sources of deterioration.

As reported in Mugwindiri and Mbohwa (2013), AM can provide many benefits to organizations. By practicing AM continuously, machines can run on, close to, the full capacity. Breakdowns of machine also may occur rarely, so as to capital expenditure is reduced. In consequences, products are produced to specification, and cleanliness and pride improves the working environment.

The general procedure for AM practice usually consists of the following seven steps (Tsang and Chan, 2000):

i. Initial cleaning and inspection of all equipment
ii. Eliminate for the causes and effects of dirt and dust
iii. Define standards of cleaning, lubricating and tightening
iv. General inspection training for all team members
v. Equipment inspection checks on a frequent basis
vi. Workplace management and control
vii. Continuous improvement

© This item is protected by original copyright

Steps 1 to 5 of the AM deal with machine improvement. These steps aim to decrease the machine life variability and extend the average lifespan of the machine. While steps 6 to 7 deal with the process improvement; aiming to improve product lifespan and design lifespan (Mckone and Weiss, 1998).

2.2.2 Technical Issue of Autonomous Maintenance

© This item is protected by original copyright

TPM program is designed to maximize the Overall Equipment Effectiveness (OEE). It involves all departments and employees from top management to front line workers (Robinson and Ginder, 1995). In other words, TPM provides a method to keep the performance of machine and plant at its higher productive level through team work of all departments of institution. The issue of application and implementation of AM have been reported by some researcher.

Many studies discussed on the concept that AM as a sub-set of TPM framework (Tsang, 2002; Chan et al., 2005; and Campbell and Reyes, 2006). Brah and Chong (2004) conducted a research concerning analyzing the relationship between TPM implementation and performance. The authors reported the AM application from the aspect of management. McKone et al. (2001) investigated the relationship between six elements of manufacturing performance and seven TPM elements, in which four of them are come from AM activities. A few research reported a case studies in TPM implementation (Tsang and Chan, 2000; and Eti et al., 2004). Both studies stated that the management team should be highly committed in implementing an AM program. Recently, Ahuja and Khamba (2008) suggested future work in TPM and AM research.