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FOREWORD

People may hear your words, but they feel your attitude.
John C. Maxwell

It is my delight and joy to be able to write my brief thoughts for this compilation of research papers by the participants of the Academy Faculty Development Program. More than just words describing their research ideas in their infancy or completed research in their final phase of write-up, this publication is intended for reader to feel their exemplary attitude held throughout the program and the willingness to take the step towards making themselves the complete academics. I am positive that the outcome of the program is an upsurge of interest in teaching and research. All the participants had benefited from the development of the thinking and dialogue initiated and it is now their obligations to tell the UNTAR community about how to develop teaching excellence and do research that will impact the world of science or social science.

The linkage between research and teaching must never be forgotten. Research informs teaching and teaching inspires research. Research is a particular way of asking questions, albeit hard questions sometimes so that useful understanding can flow. Implicit in our teaching are many aspects of the scientific method as it is actually practiced in the research. There are new bodies of knowledge that we can draw on to reflect on our teaching practice and improve our ability to think about how we should teach. In the end, our research efforts will benefit our students by making their UNTAR experience unique as they will have a headstart in deciphering the intricacies and complexities of the real world in which they will be the future citizens.

So, please continue to improve upon your ability to reflect on what you are doing and what would be a meaningful outcome as an academic. I am really pleased that this is the second step in a continuing process to enhance the quality of teaching and research.

My special thanks go to Prof. Ir. Roesdiman Soegiarso for his vision and continuing support, as well as Mr Richard Andrew and Ms Verawati who worked tirelessly to see the program come to fruition. Also thanks to A/P Ooi Chui Ping who has worked with me to pull this publication together.

Dr Chong Chee Leong, Clanworks, September 2015.

ANALYSIS OF KEY SUCCESS FACTORS IN IMPLEMENTING TOTAL PRODUCTIVE MAINTENANCE IN MANUFACTURING INDUSTRY

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ABSTRACT

This paper discusses an empirical study to examine the impact of the implementations of planned maintenance, autonomous maintenance, and focused improvement, in the framework of Total Productive Maintenance (TPM), whether provide ,. a significant and positive impact on the performance of manufacturing industry. This study was conducted using approach of Structural Equation Modeling {SEM). The purpose of this study are to analyze the key success factors in implementing TPM in manufacturing industry, and also to examines the relationships between latent variables each others in determining the successful implementation of TPM. Data were collected by distributing questionnaires to three large-scale manufacturing industry in Indonesia that have implemented TPM, with total sample is 212. Finally, t-test was used to draw the conclusions from the research hypotheses that had been formulated.

Keywords: total productive maintenance, planned maintenance, autonomous maintenance, focused improvement, performance.

INTRODUCTION

In the era of the ASEAN Community by 2015, every company should strive to improve competitiveness and productivity. To confront this challenge, the company is required to make improvements on their performance by benchmarking against their competitors. They could adopt and adapt one of the "best in class" manufacturing practices and improvement processes, such as Total Productive Maintenance (TPM). According to Nakajima {1989), TPM is a methodology for continuous improvement in manufacturing processes by involving and empowering all employees, as well as to obtain feedback on the overall performance measurement system which would be used as a input for improvement. According to Tsuchiya {1992), TPM is designed to maximize overall equipment effectiveness (OEE) by building productive maintenance system which applies on all equipments and involving all employees from the level of top management to the production floor workers, as well as encourage the productive maintenance through activities of the small team which is formed. Mckone et al, (2001) suggested that the TPM provides a world-class enterprise approach regarding maintenance management, which is divided into two parts, namely: Jong term and short term. For the long term, TPM efforts focus on the design of equipment that is easy to operate, easy to clean, easy to maintain, and can eliminate the losses that occurred, as well as specifically involves many sections of an organization. As for the short term, the activities of the JPM include the autonomous maintenance program for the department of production and the planned maintenance program for the maintenance department.

This study discusses an empirical study to examine the influence of the implementations of planned maintenance, autonomous maintenance, and focused improvement, in Total Productive Maintenance (TPM) framework, whether provide a significant and positive impact on the performance of manufacturing industry. This study aims to analyze the key success factors in implementing TPM in manufacturing industry. And also, this study examines the relationships between latent variables each others in determining the successful implementation of TPM.

LITERATURE REVIEW

Introduction of Total Productive Maintenance

At early time, the mechanization of a production equipment was still limited, simple and also designed with a high safety consideration so that precautions weren't required. Even, maintenance activities were carried out when the machine had been damaged (known as hreakdown maintenance).

After the World War II, the supply could not meet the demand so that caused the need of machining to be increased. People began to think that the equipment failure could be detected and prevented, so that the concept of preventive maintenance (19S1) was first introduced in America. Furthermore, Nippondenso, a supplier of electrical parts to Toyota, was a first company to introduce preventive maintenance in Japan in 1960. In this concept, the maintenance division was responsible for all maintenance activities of production facilities in the factory. Therefore, the maintenance cost was increased due to the transformation process of mechanization into automation in industrial processes. It required higher maintenance activities so that it needed to increase the number of maintenance personnel. So, the management involved the operators in performing routine maintenance on production equipment (known as autonomous maintenance). Maintenance division handled the essential maintenance work, including modifications of equipment to improve reliability {known as maintenance prevention - 1960). Preventive maintenance is done along with maintenance prevention and maintainability improvement is known as a new concept called productive maintenance. Then, Nippondenso established quality control circle and involve all employees in implementing productive maintenance. And, this company became the first company which got Distinguished Plant Award (the PM Prize) from the Japan Institute of Plant Maintenance {JIPM).

Implementing Total Productive Maintenance

According to the JIPM, there are 8 main pillars in the implementation of TPM as illustrated in Figure-1, namely (Gasperz, 2012: 491-S82}:

a. **Foundation #0:** Building a culture of SS

   Before building the eight pillars of TPM, should first put into practice the principles of SS (sort, stabiliz-e, shine, standardize, sustain) management as the foundation and a systematic approach to improving the working environment, processes, and products by "involving a ll employees in the production line.

b. **Pillar #1:** Autonomous maintenance

   Autonomous maintenance, also called as Jishu Hozen, is a process in which the operator has the responsibility for the performance and the condition of the machine that they handle. In this pillar operator will have the task to perform minor maintenance actions. There are seven steps in autonomous maintenance, among others: 1) initial cleaning; 2) preventive cleaning measures; 3) development of cleaning and lubrication standards; 4) general inspection; 5) autonomous inspection; 6) process discipline; 7) independent autonomous maintenance.

c. **Pillar #2:** Focused improvement

Focused improvement, also called as Kobetsu Kaizen, includes all activities that maximize the effectiveness of the equipment, process, or plant by reducing losses and increasing the percentage of overall equipment effectiveness (OEE).

d. **Pillar #3**: Planned maintenance

Planned maintenance is maintenance which is carried out periodically and regularly to prevent the production equipment from deteriorating conditions or breakdown. The purposes of the planned maintenance are to achieve and ensure the availability of production equipment with optimum maintenance costs, reduce spare parts inventory, and improve both of the reliability and maintainability of the equipment.

e. **Pillar #4 :** Early management

In this pillar there are 2 parts, namely: early equipment management, and early product management. Both serve to reduce the possibility of losses from the design of production equipment or product.

f. **Pillar #5** : Quality maintenance

The main objective of this pillar, also called as hinshitsu hozen, is to ensure the quality of products 100% {zero defects oriented).

g. **Pillar #6**: Training and education

In TPM, the training will be given mainly to operators and maintenance personnels. The operators are given the ability to run autonomous maintenance, while maintenance personnels are given the knowledges and skills in carrying out the planned maintenance.

h. **Pillar #7:** TPM office

In TPM, the administrative staff also has a major role. Delays in information, logistics, and others can reduce the level of productivity.

With the TPM office then losses (such as: processing losses, idle losses, communication losses) caused by the administration will be reduced.

i. **Pillar#**8: Safety, health, and environment

Other objectives of the TPM are zero accident and zero pollution. Clean work environment is necessary to have a safe workplace.

Figure-1 Building 8 main pillars in implementation of TPM

There are 12 steps in the process of implementing TPM, as described by Seiichi Nakajima in his book entitled Introduction to TPM, which are categorized into four stages (as shown in Table-1), namely: 1) preparatory stage; 2) preliminary implementation; 3) TPM implementation ; 4) Stabilization. According to the JIPM, in the early stage of TPM process necessary to build an organizational structure for studying and promoting TPM methods and results. Successful implementation of TPM requires commitment from top management, and also a philosophy of improvement by empowering all employees.

Table-1 The JIPM TPM Process

Stage	Step
Preparatory	1. Announce top management's decision to introduce TPM
	2. Launch an educational campaign to introduce TPM
	3. Create an organizational structure to promote TPM
	4. Establish basic policies and goals of TPM
	5. Form a master plan for implementing TPM

Preliminary Implementation	6. Kick off TPM
TPM Implementation	7. Improve the effectiveness of each critical piece of equipment
	8. Set up and implement autonomous maintenance
	9. Establish a planned maintenance system in the maintenance department
	10. Provide training to improve operator and maintenance skills
	11. Develop an early equipment management program
Stabilization	12. Perfect TPM implementation and raise TPM levels

METHOD

This study was conducted using approach of Structural Equation Modeling (SEM) to examine the relationship between latent variables. Data were collected by distributing questionnaires to three large-scale manufacturing industry in Indonesia that have implemented TPM. The questionnaire was designed based on the pillars or key indicators of successful implementation of TPM in the manufacturing industry, as well as adapted from the instrument of research that had conducted similar study (Cua et.al., 2001; McKone et.al., 2001). The questionnaire consists of 20 statements that would be assessed by the respondents using an ordinal scale from rating 1 to 4, where 1means strongly disagree, while 4 means strongly agree. These statements are divided into 4 variables, which consist of planned maintenance, autonomous maintenance, focused improvement, and performance. Planned maintenance, denoted as PM, includes the planning and scheduling of maintenance, spare parts management, a system of regular maintenance, and others related to the implementation of the planned maintenance system. Autonomous maintenance, denoted as AM, includes the initial cleaning (including housekeeping at the production area), debriefing training concerning machine maintenance to operators, team building between the production and maintenance, and autonom_ous maintenance (handling minor damage) that performed by the operator. Focused improvement, denoted as FI, includes the entire activities in improving the reliability, ease of operation, and maintainability of the production equipment which aims to reduce the losses that occur. Performance, denoted as PERF, includes both in terms of qua lity and productivity. The following are the hypotheses formulated in accordance with the research model, as shown in Figure-2:

a. Hypothesis 1: Planned maintenance implementation has a positive and significant effect towards performance in manufacturing industry.
b. Hypothesis 2: Autonomous maintenance implementation has a positive and significant effect towards performance in manufacturing industry.
c. Hypothesis 3: Focused improvement implementation has a positive and significant effect towards performance in manufacturing industry.
d. Hypothesis 4: Planned maintenance implementation has a positive and significant effect towards focused improvement.
e. Hypothesis 5: Autonomous maintenance implementation has a positive and significant effect towards planned maintenance.
f. Hypothesis 6: Autonomous maintenance implementation has a positive and significant effect towards focused improvement.

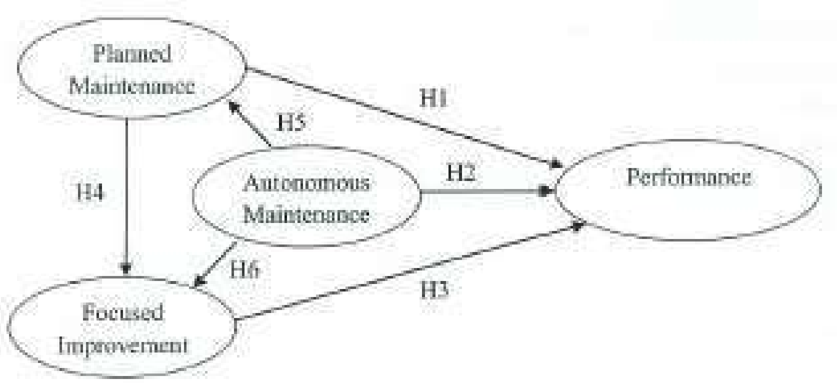

Figure-2 Hypothesis and conceptual model

According to Boomsma (1987 in Arbuckle, 1997), the sample size for SEM is at least 200. The sample total of this study is 212. From the data obtained, the measurement model of each variable were developed . Furthermore, each model was tested goodness of fit, validity, and reliability. Attributes that was not valid or not reliable would be removed and then tested again. In SEM, the measured variable is valid if it has a standardized loading factor ;?: 0.5, and it would be reliable if it has a composite reliability ;?: 0.7 and a variance extracted 0.5. Here is a formula that could be used to calculate the composite reliability (Bollen, 1989):

$$Composite\ reliability = \frac{(\sum std\ loading\ factor)^2}{(\sum std\ loading\ factor)^2 + \sum e_j} \quad (1)$$

And, the following is a formula that could be used to calculate the variance extracted (Fornell & Larcker, 1981):

$$Variance\ extracted = \frac{\sum (std\ loading\ factor)^2}{\sum (std\ loading\ factor)^2 + \sum e_j} \quad (2)$$

After that, the full structural model had been developed and would be retested goodness of fit. T tests was conducted on the ..model to test the whole hypotheses that had been formulated so that it would know whether HO accepted or not.

DISCUSSION AND RESULT

Structural model that developed (as seen in Figure-3) showed that the direct effect of PM implementation towards the implementation of FI and performance respectively by 0.45 and 0.53. Similarly, the implementation of FI has a direct effect towards the manufacturing performance with value of 0.57. There is a direct effect of AM implementation towards FI implementation with value of 0.48 while its indirect effect with value of 0.22. As well as, the direct effect of AM implementation towards the performance with value of 0.11 and its indirect effect with value of 0.54. Meanwhile the total effects of AM implementation, PM implementation, and FI implementation towards the performance respectively by 0.50, 0.70, and 0.65. The following is a mathematical equation that describes the correlation of all three variables simultaneously towards the performance in the manufacturing industry:

Performance = 0.28*PM + 0.57*FI + 0.11*AM, Errorvar = 0.26, R^2 = 0.74 (3)

The model indicates good fit, which obtained root mean square residual (RMSR) with value of 0.032, and fix comparative index (CFI) with value of 0.93. Based on results of validity and reliability tests as seen in Table-2, most of the variables had demonstrated valid and reliable, and only VAR8 which was invalid and removed. Analysis of the coefficient of determination indicates that VAR4 (R^2 = 0.64) is an indicator that most represents the implementation of planned maintenance. And then, VAR10 (R^2 = 0.80) is an indicator that most represents the implementation of autonomous maintenance. As well as, VAR15 {R^2 = 0.58) is an indicator that most represents the implementation of focused improvement.

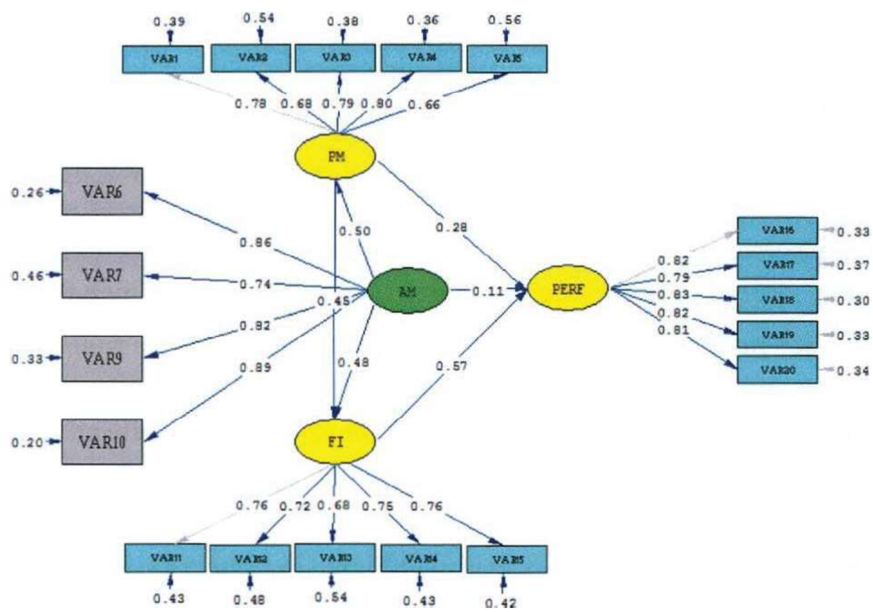

Figure-3 Empirical Model

Table-2 The results of confirmatory factor analysis

Latent variables	Measured variables	Standardized Loading factora	R2	Error	Composite Reliabilityb	Variance Extractedc
Planned Maintenance (PM)	VAR1	0.78	0.61	0.39	0.86	0.55
	VAR2	0.68	0.46	0.54		
	VAR3	0.79	0.62	0.38		

	VAR4	0.80	0.64	0.36		
	VARS	0.66	0.44	0.56		
Autonomous Maintenance (AM)	VAR6	0.86	0.74	0.26	0.90	0.69
	VAR7	0.74	0.55	0.46		
	VAR9	0.82	0.67	0.33		
	VARIO	0.89	0.79	0.20		
Focused Improvement (FI)	VAR11	0.76	0.58	0.43	0.85	0.54
	VAR12	0.72	0.52	0.48		
	VAR13	0.68	0.46	0.54		
	VAR14	0.75	0.56	0.44		
	VARI S	0.76	0.58	0.42		
Performance (PERF)	VAR16	0.82	0.67	0.33	0.91	0.67
	VAR17	0.79	0.62	0.37		
	VAR18	0.83	0.69	0.30		
	VAR19	0.82	0.67	0.33		
	VAR20	0.81	0.66	0.34		

al The measured variable is valid if it has standardized loading factor 0.5.
bl cl The measured variable is reliable if it has composite reliability 0.7 and variance extracted 0.5.

T test results showed that only hypothesis 2 which received HO due to has t-value of 0.92 (< 1.96). It means there is no significant effect of the implementation of autonomous maintenance towards the performance. Whereas, all other hypotheses reject HO for detail as seen in Table-3.

Table-3 The results of hypothesis test*

Hypothesis	t-value	Result	Meaning
Hl: PM -7 PERF	2.28	Reject H01	Positive and significant effect
H2: AM -7 PERF	0.92	Accept H02	No significant effect
H3: FI -7 PERF	3.39	Reject H03	Positive and significant effect
H4: AM -7 PM	4.06	Reject H04	Positive and significant effect

HS: PM-7FI	3.66	Reject HOs	Positive and significant effect
H6: AM-7FI	4.03	Reject HOG	Positive and significant effect

*) Hypothesis testing using two-tails test.

CONCLUSIONS

This empirical study proves and confirms that there are a positive and significant effect of the implementations of planned maintenance and focused improvement, in TPM practice, towards performance of the manufacturing industry. The model shows that the implementation of focused improvement is the most impact on the performance, compared with others. Meanwhile, the implementation of autonomous maintenance apparently doesn't provide a significant direct effect on the performance. Nevertheless, autonomous maintenance provides significantly positive influence on the implementations of planned maintenance and focused improvement. Similarly, success in implementing planned maintenance have a significant influence positively on the implementation of focused improvement. Based on the analysis of coefficient of determination shows that "the standardization of maintenance work in optimum condition" is an indicator that most represents the implementation of planned maintenance; In autonomous maintenance, "the forming of small team from both production dept and maintenance dept" is an indicator that most represents it; and "the maintenance activities that focus in improving workplace safety" is an indicator that most represents the implementation of focused improvement.

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