A Study of Total Productive Maintenance (TPM) and Lean Manufacturing Tools and Their Impact on Manufacturing Performance

Herry Agung Prabowo, Erry Yulian Triblas Adesta

Abstract*— *In Indonesia, companies that have correctly implement TPM and LM are still very limited. They also implement TPM without being integrated with LM. To look beyond their implementation and their impact to manufacturing performance, a research through survey method have been conducted. The 250 questionnaires have been sent to 125 manufacturing companies located in Jakarta, Bekasi, Tangerang, Bandung and Lampung. 105 have been returned but only 91 questionnaires suitable for further processing using Structural Equation Modelling (SEM) with Smart-PLS as a programming tool. Almost all of 8 Pillars of TPM were considered valid, reliable and significant to represent the TPM implementation in Indonesia. All of 8 LM tools were also considered valid, reliable and significant. TPM have a strong correlation with LM and a moderate correlation with MP. LM also has moderate correlation with MP. TPM pillars and LM tools together affect MP as much as 60.9% (R2 = 0.609). It also means that 60.9% variability of MP can be explained by TPM and LM while 39.1% can be explained by others.

Keywords: TPM; Maintenance; Lean; Manufacturing; SEM

1. INTRODUCTION

1.1 Background

The structural transformation process of Indonesia economics during 1990-2017 was very influenced by manufacturing industry sector. In 2000, the contribution of manufacturing sector reached nearly 30% of the Indonesia's GDP. Unfortunately, the contribu-tion decreased several times in the following years and as low as 20% of the total GDP in 2017 (as provided in Table 1).

Table 1: Sectorial Contribution in the Indonesian Economics 1990-2017 [1]

Year	Agricultural (%)	Manufacturing (%)	Others (%)
1995	15.6	20.3	54.3
2000	13.9	30.0	64.3
2010	13.7	23.2	65.1
2012	13.7	21.5	65.5
2015	13.7	21.2	60.2
2017	13.8	20.2	66.0

It can be concluded that Indonesia's manufacturing sector play an important role in Indonesian economics. In fact, the Indonesia's manufacturing performance was not good enough. They were still having low Overall Equipment Effectiveness (OEE), low Reliability and high breakdown [2-4]. To overcome this problem Indonesian manufacturing companies needs a modern and comprehensive manufacturing strategy or method to optimizing their performance. Just-in-Time, Six Sigma, Total Quality Management (TQM), Sta-tistical Proses Control, Total Productive Maintenance (TPM) and Kanban System were some of those strategies under an umbrella of Lean Manufacturing (LM) tools.

In Indonesia, companies that have correctly implement TPM and LM are still very limited. Most managers still consider TPM im-plementation to be an additional cost burden. So in most cases, maintenance is still reactive. The results of several studies indicate that many manufacturing industries in Indonesia have performance scores for machines / tools—in term of OEE—below the world class standard by JIPM with minimum OEE = 85%. Research from [1], [2] and [3] found that OEE value were only between 27% – 77% far enough from world class OEE. While [4] and [5] found that non-value added activities in their industries were considered to be still quite high, that is around 41% – 70%. It can be concluded that the practices of LM and TPM in Indonesia's manufacturing industry are still far away from world-class performance. They are still focused on efforts to overcome implementation barriers. They also implement TPM without being integrated with LM. To achieve operational excellence, the TPM and LM integrated implementation models and the effects of both on MP are very important to be built and implemented. By providing LM and TPM current practices conditions, combined with reference models of relationships between LM, TPM, and MP important archives for academics and practitioners (industry) can be created.

1.2 Literature Studies

The pressure to further increase the machine reliability gets even higher with the implementation of Just-in Time from Toyota Production System and any Lean Manufacturing tools which is compliant to the zero inventories, zero breakdown and eliminated non value-added activities. LM tools/programs have limits that are determined by the low machine or equipment reliability and availability.

Revised Manuscript Received on March 05, 2019.

Herry Agung Prabowo, Manufacturing and Materials Engineering Department, International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia and Universitas Mercu Buana, Jakarta, Indonesia

Erry Yulian Triblas Adesta, Manufacturing and Materials Engineering Department, International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia

This will force the company to consider the necessity of a maintenance program [6], [7]. A maintenance program which is considered as one of LM tools and techniques is TPM [8].

TPM is one of a Lean Manufacturing (LM) tools focus on optimizing machine and process productivity and an important pillar in the continuous improvement process [8]. TPM is an innovative maintenance approach to eliminate failures/breakdowns, optimize equipment effectiveness, and promote autonomous maintenance by operators of daily activities involving all employees [9]. TPM is a maintenance and production program that is designed primarily to maximize the effectiveness of all tools through the participation, engagement and motivation of all staff / employees [11-14].

The Toyota Production System (TPS) was the first LM concept in the 1970s which was driven by the Japanese Toyota automotive company and officially called "Lean" by Krafcik and Womack which developed rapidly in North America during the 1984-1994 [10], [11]. [12] and [13] provide a brief description of the various LM tools and techniques available: Just-in-time, TPM, Cellular Manufacturing, Continuous Improvement, Work Standardization and Production Smoothing.

The significant contribution of LM implementation in improving business performance is through the elimination of waste (7 wastes), namely: defects, inventory, transportation, waiting, motion, excess production, and excess processing [13]. The amount of waste produced in the manufacturing process has a strong relationship with the performance of the machine or equipment. Strategic maintenance management such as TPM is thus very necessary to ensure the success of lean production. Figure 1 shows the relationship between various manufacturing philosophies with TPM and LM. It is very clear that TPM is a cornerstone activity for most LM strategies and has a significant contribution to the successfulness LM.

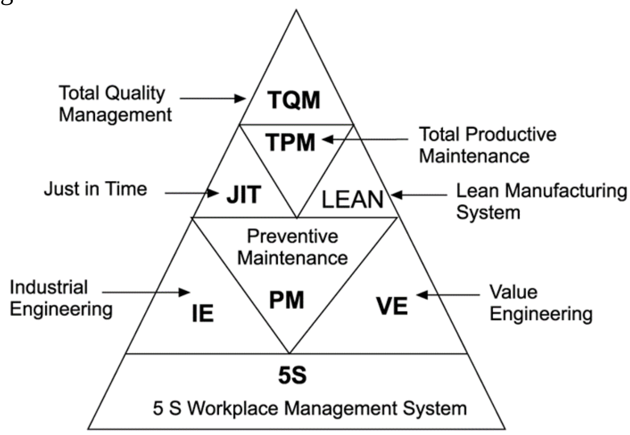

Fig. 1: Relationship between TPM, LM and others philosophies Ahuja in [14]

Many companies try to improve their business performance through the application of TPM or LM methods. However, most of these implementations are carried out separately. Both TPM and LM have their own strengths and have a significant impact on supporting others. Comprehensive integration between the two methodologies is recommended to be studied further rather than just focusing on a particular methodology according to the current trend.[15]. An effective plant will be more achievable if those initiatives been integrated into one set of manufacturing practice. There is a need for a further research to comprehensively integrate these two initiatives and their impact to MP (manufacturing performance). With this in mind, there is a slant to provide a ground to study their integration in manufacturing industries.

1.3 Research objectives

From the previous explanation, this research have some objectives as follow:

1. To generate evaluation of TPM and LM current practices.
2. To develop outer models (measurement models) for TPM, LM and MP.
3. To proposed inner model (structural model) of the impact of the implementation of TPM and LM on manufacturing performance (MP).

1.4 Research Hypothesis

In this research four hypotheses have been tested (H1 to H4) namely:

a. H1: TPM pillars have positive and significant relationship to Lean Manufacturing (LM);
b. H2: TPM pillars have significant impact to MP;
c. H3: LM tools have significantly impact to MP.
d. H4: TPM and LM practices have significant and positive impact to MP.

2. MATERIALS AND METHODS

2.1 Research materials

For data collecting, 250 questionnaires have been sent to 125 manufacturing companies located in Jakarta, Bekasi, Tangerang, Bandung and Lampung. 105 have been returned but only 91 questionnaires suitable for further processing. Most of the rejected questionnaires were due to very incomplete filling and the same answers to all questions.

2.2 Research method

From the previous research, many researchers treated TPM and LM as an observed variable instead of un-observed one. Not many researchers treated TPM, LM and MP as un-observed variables namely [16],[12],[17] and [18]. In this research, TPM and LM's variables treated as un-observed variables (latent variables) and measured them through their indicators. CFA (Confirmatory factors analysis) and SEM (Structural Equation Modelling) is the appropriate method to perform the analysis.

2.3 Research steps

Research activities will follow these steps:

1. From previous research: determine TPM, LM and MP indicators/variables.
2. Models formulating (Measurement/outer and Structural/inner) using SEM method.
3. Generating questionnaires and sending them to 120 selected companies.

4. Data collecting and processing using Smart-PLS software.
5. Analysing, Comparing and make conclusion.

2.4 Research variables

There were 3 construct or latent variables in this research namely TPM pillars, LM tools and MP. As mentioned earlier, TPM Pillars has become an initial requirement for the successful LM im-plementation so it is necessary to examine what TPM pillars are influential on the implementation of LM. Determination of research variables for TPM Pillars refers to several previous studies namely [9], [19] and [20]. According to them, there are 8 pillars namely: 1. Autonomous Maintenance, 2. Planned Maintenance, 3. Continuous Improvement, 4. Quality Maintenance, 5. Education and Training, 6. Safety, Health and Environment, 7. Office TPM, 8. Development Management. [12], [13] and [21] for LM tools. There are also 8 tools for LM strategies according them namely: 1. Cellular Manufacturing, 2. Standardized Work, 3. Just in Time, 4. Continuous Improvement, 5. Production Smoothing, 6. Value Stream Mapping, 7. Statistical Process Control , 8. Supplier Involvement. Whereas the MP variable is taken from [9], [18], [22] and [14] namely: 1. Quality, 2. Cost, 3. Delivery, 4. Flexibility, 5. Overall Equipment Effectiveness (OEE).

2.5. Determination of standard values for evaluation

The first stage in data processing is to generate a measurement model to test the validity and reliability of all indicators whether it can truly represent the construct variables. In other words, to look at the relationship between indicators and their respective construct variables. The values used as reference are the value of Loading Factor and AVE (Average Variance Extracted) to test the validity (convergent) of the measurement model (outer model). Composite Reliability (CR) value and Cronbachs Alpha (CA) used for the reliability test of the model [23]. After testing the validity and reliability, continued with a significance test using Bootstrapping method to generate T-statistics value. Furthermore, a structural model (inner model) is developed which aims to see the relationship between both Exogenous and Endogenous construct variables, by looking at the R, R2 and Goodness of Fit values of the model. To evaluate those values, rules of thumb of evaluation have been provided in Table 2 and Table 3 (adopted from Chin, and Haier et al. in [23].

Table 2: Rules of Thumb for Measurement Model Evaluation

Validity and Reliability	Parameters	Rule of Thumb
Convergent Validity	Loading factors	• > 0.70 for confirmatory research • > 0.50 for exploratory research
	AVE	• > 0.50 for both confirmatory and exploratory research
Reliability	CA	• > 0.70 for confirmatory research • > 0.60 for exploratory research
	CR	• > 0.70 for confirmatory research • > 0.60 for exploratory research

Table 3: Rules of Thumb for Structural Model Evaluation

Criterion	Parameters	Rule of Thumb
Significances	T statistic	• >1.65 for 10% significant level • >1.96 for 5% significant level • >2.58 for 1% significant level
	P-value	• >0.05 for any significant level
Correlation	R	• > 0.70 Strong • > 0.31 Moderate • < 0.31 Weak
Prediction	R^2	• > 0.67 Strong • > 0.33 Moderate • < 0.33 Weak

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Measurement (outer) model evaluation

Using Smart-PLS 3.0 as a processing tool, generated several models and tables as follows:

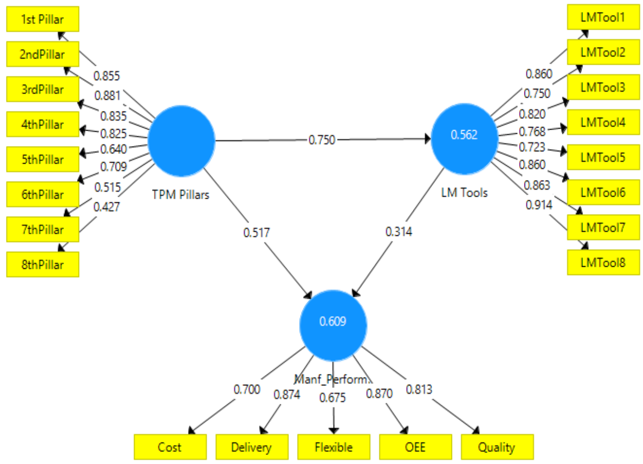

Fig. 2: CFA and SEM for TPM Pillars, LM Tools and MP

Table 4: Loading Factors for Construct Variable TPM Pillars

Indicators	Loading factor	Conclusion
1st Pillar: Autonomous Maintenance	0.855	Valid
2nd Pillar: Continuous Improvement	0.881	Valid
3rd Pillar: Planned Maintenance	0.835	Valid
4th Pillar: Quality Maintenance	0.825	Valid
5th Pillar: Education and Training	0.640	Valid
6th Pillar: Safety, Health, Environment	0.709	Valid
7th Pillar: Office TPM (Supporting)	0.515	Adequate
8th Pillar: Development Management	0.427	Not Valid

From Figure 2 and Table 4 it can be seen that according to Table 2 there are 6 indicators/pillars that can be considered valid representing the implementation of TPM in today Indonesian manufacturing companies. In other words, it can be said that the 6 pillars of TPM have been implemented and run very well, they were 1st Pillar, 2nd Pillar, 3rd Pillar, 4th Pillar, 5th Pillar and 6th Pillars which have loading factor

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

value greater than 0.70. 1 pillars (7th Pillar) have been considered less valid because of loading factor value less than 0.70. However, according to Table 2 on the level of development/exploratory research, loading value > 0.50 can still be considered adequate. Only 8th Pillar was considered not valid representing TPM because of loading factor value less than 0.50. This means that this pillar activity is only related to TPM less than 50% so that it cannot represent the TPM pillar

Table 5: Loading Factors for Construct Variable LM Tools

Indicators	Loading factor	Conclusion
1st Tool: Cellular Manufacturing	0.860	Valid
2nd Tool: Value Stream Mapping	0.750	Valid
3rd Tool: Just in Time and SMED	0.820	Valid
4th Tool: Continuous Improvement	0.768	Valid
5th Tool: Production Smoothing	0.723	Valid
6th Tool: Standardized Work	0.860	Valid
7th Tool: Statistical Process Control	0.863	Valid
8th Tool: Supplier Involvement	0.914	Valid

From Table 5 it can be seen that all indicators for LM tools variables are valid because they have a loading factor of greater than 0.70.

Table 6: Loading Factor for Construct Variable MP

MP Indicators	Loading factor	Conclusion
Quality	0.813	Valid
Cost	0.700	Valid
Delivery	0.874	Valid
Flexibility	0.675	Valid
OEE	0.870	Valid

From Table 6 above it can be said that all of indicators were considered valid representing the construct variable MP because all of the loading factors were greater than 0.70.

Table 7: Validity and Reliability Test

Variables	Cronbachs Alpha (CA)	Composite Reliability (CR)	Average Variance Extracted (AVE)	Conclusion
TPM Pillars	0.864	0.896	0.531	Reliable
LM Tools	0.931	0.943	0.676	Reliable
Manufacturing Performance	0.846	0.892	0.626	Reliable

Table 7 shows that all indicators have been Valid and Reliable to measure all variables (TPM Pillars, LM Tools and MP) because of all CR and CA values are greater than 0.70 and all AVE values are greater than 0.50 (see Table 2).

3.1.2 Structural (Inner) Model Evaluation

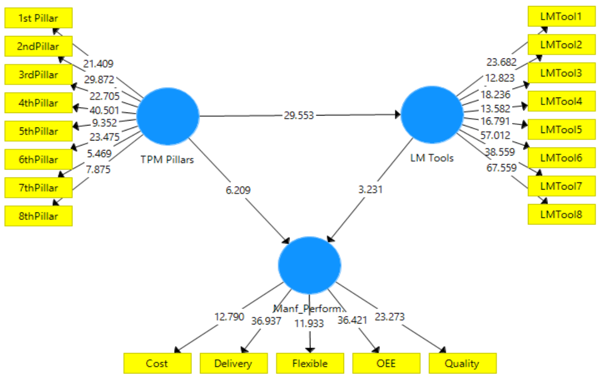

Fig. 3: Bootstrapping for TPM Pillars, LM Tools and MP

Table 8: Path Coefficients: T statistics and P-values

	t- statistics	P Values
LM Tools → Manf Perform	3.420	0.001
TPM Pillars → LM Tools	25.853	0.000
TPM Pillars → Manf Perform	6.657	0.000

Figure 3 and Table 8 shows that T-statistics for all variables were greater than 1.96 and P-values are less than 0.05 means that all relationships between indicators and variables construct are significant at 95% confidence level. Its mean that all of values generated can be used for analysis stage.

Table 9: Path Coefficients: Correlations (R)

Variables Construct	LM Tools	TPM Pillar	Manufacturing Performances
TPM Pillars	0.750	----	0.517
LM Tools	----	----	0.314

Table 10: R square (R2) and R2 Adjusted

Variables	R square (R^2)	R^2 Adjusted
LM Tools	0.562	0.557
Manuf.Performance	0.609	0.600

Table 9 shows the correlation values between variables. TPM pillars and LM tools have a positive and strong correlation. While the correlations between TPM and LM with MP are both moderate and positive. Table 10 shows that 56.20% variability of LM tools can be explained by TPM pillars. While 60.90% variability of MP can be explained by TPM pillars and LM tools simultanously.

3.2 Discussion

3.2.1 TPM and LM implementation in Indonesia

In general from the result above, the implementation of TPM Pillars and LM tools in Indonesian manufacturing industries have been running smooth and quite well. 7 pillars TPM were considered valid and only 1 pillar was less valid. This result is generally better with the results of research by [24] where only 6 pillars are considered valid representing TPM. Invalid indicators, in this [24] research are the 3rd pillar, namely Planned Maintenance and the 8th pillar namely Development Management. Further compared with other studies from [16] the results are even better, because [16] only stated 2 significant pillars. But the results was less better comparing with [22] that all of the pillars were valid to represent TPM. Besides the number of more valid pillars in this study also has a relatively higher average loading factor value of 0.70 compared to 0.50 in [24].

For the application of LM tools, all of 8 LM tools are considered valid, reliable and significant. This research has relatively similar results to the research conducted by [25] which also found the number of valid LM tools is 8 tools. In terms of the average value of the loading factor is also relatively the same, which is 0.80, a fairly high value.

3.2.2 The i of applying TPM pillars and LM tools to MP

In this study it is known that the correlation between TPM pillars and MP is quite good or moderate with R value = 0.517 (see Table 9).

This result have a similar result with [26] that TPM have a moderate correlation with MP, but different with research from [24] which resulted in a strong correlation between TPM pillars and MP. This different caused by not the same variables used to measure MP performance. In this study 5 MP indicators are used, namely: Q, C, D, F and OEE. While in the [24] research only uses 2 performance indicators namely OEE and waste (decreased waste).

While the correlation between LM tools and MP in this study also exists at a moderate value limit with R value = 0.314 (see Table 9). This result is relatively same with [26] that LM have a moderate correlation with MP (R = 0.435) but lower than the value generated by [27] which is R = 0.637. The difference in correlation values is most likely due to differences in MP indicators, where Adesta 2018 research includes indicators of waste (decrease waste) indicators which are theoretically the target of LM implementation [13].

3.2.3 Test of hypotheses

Table 8, Table 9, and Table 10 are used to answer the hyphotheses test (H1-H4). H1: TPM has a significant relationship with MP is accepeted at confidence level 95% because P value = 0.000 < 0.05. The relationship between TPM and MP can be explained by R value = 0.750 and R2 = 0.562 (as shown in Table 8 and 9), it means that TPM Pillars has a positive and strong correlation with LM tools (according to Table 3). H2: TPM Pillars has significant impact to MP is accepted at moderate correlation with value of R= 0.517. H3: LM tools have significantly impact to MP is TRUE. H4: TPM and LM practices have significant and positive impact to MP is accepted. Where the effect of TPM pillars and LM tools on MP is 60.9% while the remaining 39.1% is influenced by other variables.

4. CONCLUSION

This study provides rather unexpected results, namely the good implementation of TPM's pillars and LM' tools in the Indonesian manufacturing industry and the influence of both on manufacturing performance is quite large, given that the Indonesian industry has not known the length and time of applying these methods. However, the results of this study can be the basis for further research in the same field and for futher development strategy for Indonesia Goverment.

REFERENCES

1. D. Triwardani, A. Rahman, and C. Tantrika, "Analisis Overall Equipment Effectiveness (OEE) dalam Meminimalisi Six Big Losses Pada Mesin Produksi Dual Filters DD07 (studi kasus : PT. Filtrona Indonesia, Surabaya, Jawa Timur," Jur. Tek. Ind. Univ. Brawijaya, vol. 07, pp. 379–391, 2012.
2. H. A. Prabowo and D. I. R, "Improve the Work Effectiveness With OEE (Overall Equipment Effectiveness) As the Basis for Optimizing Production," Pasti, vol. IX, no. 3, pp. 286–299, 2014.
3. E. Kuncoro and A. DSE, "Analisis Perawatan dan Efektivitas Mesin Kontinyu," in Seminar Nasional Inovasi dan Aplikasi Teknologi di Industri, 2018.
4. F. Hazmi, K. PD, and H. Supriyanto, "Penerapan Lean Manufacturing untuk Proses," J. Tek. ITS, vol. 1, no. 1, pp. 135–140, 2012.
5. H. Khannan, MSA., "Analisa Penerapan Lean Manufacturing untuk Produksi," Rekayasa Sist. Ind., vol. 4, no. 1, pp. 47–54, 2015.
6. F. Tajri, M., Gotoh, TPM Implementation: A Japanese Approach. New York: McGraw Hills, 1992.
7. M. . Ahmed, T., Ali, S.M., Allama, M.M, Parves, "A Total Productive Maintenance (TPM) Approach to Improve Production Efficiency and Development of Loss Structure in a Pharmaceutical Industry," Glob. J. Manag. Bus. Res., vol. 10, no. 2, pp. 186–190, 2010.
8. Y. Mishra and M. Aarif, "Total Productive Maintenance," Emerg. Trends Eng. Manag. Sustain. Dev., 2016.
9. I. P. S. Ahuja and J. S. Khamba, "Total productive maintenance: literature review and directions," Int. J. Qual. Reliab. Manag., vol. 25, no. 7, pp. 709–756, 2008.
10. D. S. Womack, J.P., Jones, D.T., Ross, D., Carpenter, The Machine that Change the World. New York: Simon and Schuster Inc., 1990.
11. A. Anvari, Y. Ismail, S. Mohammad, and H. Hojjati, "A Study on Total Quality Management and Lean Manufacturing : Through Lean Thinking Approach," World Appl. Sci. J., vol. 12, no. 9, pp. 1585–1596, 2011.
12. R. Shah and P. T. Ward, "Defining and developing measures of lean production," J. Oper. Manag., vol. 25, no. 4, pp. 785–805, 2007.
13. Y. Mishra, M. Kachawaha, and K. Jain, "A Review on Lean Manufacturing & It's Implementations," Emerg. Trends Eng. Manag. Sustain. Dev. 2016, 2016.
14. E. Y. . Adesta and H. . Prabowo, "Total Productive Maintenance (TPM) Implementation Based on Lean Manufacturing Tools in Indonesian Manufacturing Industries," Int. J. Eng. Technol., vol. 7, pp. 156–159, 2018.
15. A. H. Bakri, A. R. A. Rahim, N. M. Yusof, and R. Ahmad, "Boosting Lean Production via TPM," Procedia - Soc. Behav. Sci., vol. 65, no. ICIBSoS, pp. 485–491, 2012.
16. K. E. McKone, R. G. Shroeder, and K. O. Cua, "The impact of total productive maintenance practices on manufacturing performance," J. Oper. Manag., vol. 19, pp. 39–58, 2001.
17. S. Hashim et al., "Total Productive Maintenance and Innovation Performance in Malaysian Automotive Industry," Int. J. Eng. Res. Dev., vol. 3, no. 11, pp. 2278–67, 2012.
18. V. Belekoukias, I., Garza Reyes, J., Kumar, "The impact of lean methods and tools on the operational performance of manufacturing organisation," Int. J. Prod. Res., vol. 52, no. 18, pp. 5346–5366, 2014.
19. S. Nakajima, Introduction to TPM. Porltand OR: Productivity Press, 1988.
20. D. S. Pandey and N. Raut, "Implementing TPM by doing Root Cause Analysis of the Downtime losses," vol. 3, no. 2, pp. 1399–1405, 2016.
21. S. M. Zahraee, "A survey on lean manufacturing implementation in a selected manufacturing industry in Iran," Int. J. Lean Six Sigma, vol. 7, no. 2, pp. 136–148, 2016.
22. E. Y. T. Adesta, H. A. Prabowo, and D. Agusman, "Evaluating 8 pillars of TPM implementation and their contribution to MP," IOP Conf. Ser. Mater. Sci. Eng., vol. 290, no. 1, pp. 1–9, 2018.
23. I. Ghozali and H. Latan, Partial Least Squares: Konsep Teknik dan Aplikasi Menggunakan aplikasi SmartPLS 3.0, vol. 2. Semarang: Badan Penerbit Universitas Diponegoro, 2015.
24. H. A. Prabowo, Y. Bobby, and Farida, "The Evaluation Of 8 Pillars TPM Implementation And Their Impact On Waste and OEE (Overall Equipment Effectiveness)," Sinergi, vol. 22, no. 1, pp. 13–18, 2018
25. E. Y. . Adesta and H. A. Prabowo, "The Evaluation of Lean Manufacturing Implementation and Their Impact to MP," in International Conf. on Design, Engineering and Computer Science, 2018, p. 51.
26. G. Nawanir, L. K. Teong, and S. N. Othman, "Impact of lean practices on operations performance and business performance: Some evidence from Indonesian manufacturing companies," J. Manuf. Technol. Manag., vol. 24, no. 7, pp. 1019–1050, 2013.
27. E. Y. . Adesta and H. Prabowo, "The Evaluation of Lean Manufacturing Implementation and Their Impact to MP," in Towards 3rd Generation University, Embracing Digital Technologies for Industrial Revolution 4.0 (ICDECS 2018), 2018, p. 51.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication