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The Evaluation of Lean Manufacturing Implementation and Their Impact to Manufacturing Performance

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Abstract. With more challenges in competition worldwide, manufacturing industry needs more active to provide high levels of performance and commitment. To win the competition through more customer satisfaction, manufacturing companies have to opted not only high skill human resources, latest technologies but also have the reliable and modern manufacturing optimization strategy. Lean manufacturing tools have been widely used by manufacturing companies to achieve these objectives. Many researchers have researched and explained the application of these different LM tools in industry that are mostly located in developed countries, very few have examined the application of these tools in developing countries (such as Indonesia). This paper aims to evaluate LM tools implementation and their impact on manufacturing performance in the Indonesian manufacturing companies. 50 questionnaires have been taken from 15 companies, only 32 were responded and only 30 items were suitable to be processed. Data processing was performed with Smart-PLS 3.0 program. All of 8 tools/ indicators was found valid and reliable to represent LM tools and have a Positive and Moderate relationship with manufacturing performance (MP) with R^2 = 40.6% means variability of MP 40.6% could be explained by 8 LM tools and the rest by others factors.
Keywords: *Lean Manufacturing Tools, Manufacturing Performance, Structural Equation Modeling*

1. Introduction

With more challenges in competition worldwide, manufacturing industry needs more active to provide high levels of performance and commitment. To win the competition through improve customer satisfaction, manufacturing companies have to opt not only high skill human resources, latest technologies but also have the reliable and modern manufacturing optimization strategy. Lean manufacturing principles have been widely used by manufacturing companies to achieve these objectives. There is much evidence of successful LM implementation in many developed countries. However, the success rate and LM tools applied in developing countries have yet to be investigated. Lean Manufacturing (LM) is an effort to prevent and eliminate waste so that it can increase the value-added products for consumers. LM is a way of thinking philosophy, methods and management strategies to improve efficiency in manufacturing or production lines [1]–[4].

Numbers of literature stated that there are many different tools related to LM practices/ strategies. [5] said that processes and equipment, planning and control, supplier relationship, human resources and

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customer relation were strongly significant to LM (5 principles/tools). [6] revealed that TPM, Kaizen and 5S are the most influential LM practices (3 tools). [4] gives the various lean principles/tools as follows: Cellular Manufacturing, Just in time, Continuous Improvement, Production Smoothing, Standardization of Work, and TPM. [2] shows empirically identifying 10 components (distill from 48 items) that positively and significantly represent LM tools. Total Quality Management, Six Sigma, Total Productive Maintenance, 5S, SMED, Just in Time, Kanban System, Toyota Production System, Value Stream Mapping, etc. are some examples of modern manufacturing tools, which are widely used and under the umbrella of LM strategy [7]. Many researchers have researched and explained the application of these different LM tools in industry that are mostly located in developed countries, very few have examined the application of these tools in developing countries (such as Indonesia). From this background, some questions arise, what LM tools are currently applied in the typical developing country like Indonesian manufacturing industry? What is the success rate of implementation? How does it affects manufacturing performance? This paper aims to answer these questions with a research of the evaluation of LM tools implementation and their impact on manufacturing performance in the Indonesian manufacturing industries.

2. Literature Review

2.1. Lean Manufacturing (LM)

Toyota, the Japanese automotive company was the first to propose the concept of LM during the 1950s when it was known as Toyota Production System (TPS). The first goal of TPS was to improve productivity and decrease cost by eliminating waste or non-value added activities [1],[3] and [4]. TPS growing rapidly in North America since 1984 when the formation of NUMMI a joint venture between Toyota Motor Company and General Motors opens in California and formally called as “Lean” by Krafcik and Womack in the era of 1988-1994 [1], [2], and [3]. According to Krafcik, lean means using all the fewer resources of mass production methods. In fact only half, half the workforce, half the production space, half the investment for equipment, half the production time and even half the time to develop new products than the mass production system [1]. Lean manufacturing seeks to eliminate any waste or "Muda" (Japanese) as a means of lowering costs and reducing lead time while maximizing production efficiency based on customers according to [8], [9].

LM is an organization effort to improve production efficiency and typically carried out by almost all the companies to prevent budget waste production. The use of the concept of LM is expected to reduce production costs while still maintaining the quality of the goods. LM becoming a very important part for the company in the development of LM regarded as systemic and systematic approach that works for identification to eliminate all waste as well as all the activities that are not useful. LM approach is meant to transform non-value added activity into value added activity.

Mishra [4] provides a brief explanation of the methods / tools and techniques LM commonly used as follows: Cellular Manufacturing, Just in Time, Continuous Improvement or Kaizen, Total Productive Maintenance (TPM), Production Smoothing, and Work Standardization. [2] shows 10 conceptual definition that represent LM namely: supplier feedback, JIT delivery by suppliers, supplier development, customer involvement, pull/kanban system, continuous flow, set-up time reduction, TPM, statistical process control, and employee involvement. While [10] proposes a pyramid to link various LM philosophy tools as follows:

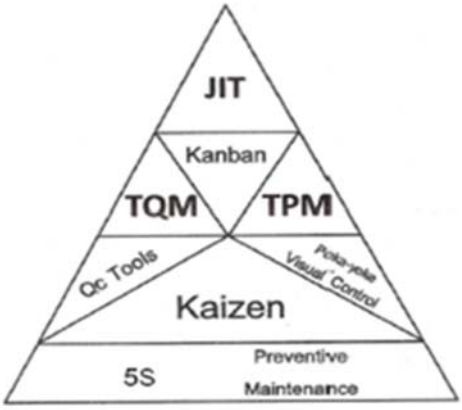


Figure 1. The Relationship between various tools/methods of LM philosophy

The picture above explains that Preventive Maintenance, Kaizen and 5S are the foundations of JIT, TQM and TPM. While QC tools are the main activities of TQM, Poka Yoke and Visual Control are the main activities of TPM, and Kanban system is a key activity in JIT. On the other hand [5] defines LM as: Cellular Manufacturing, Just in Time (JIT), Kanban, Total Productive Maintenance (TPM), Poke Yoke, Visual Control, Single-minute exchange of dies (SMED), Total quality management (TQM), and 5S. For this research we used 8 LM tools taken from [2], [4], [5] as from previous research known to be the most widely used. There were 1. Cellular Manufacturing. 2. Standardized Work, 3. JIT and SMED, 4. Kaizen / Continuous Improvement, 5. Production Smoothing 6. Value Stream Mapping 7. Statistical Process Control, and 8. Supplier Involvement.

2.2. Lean Manufacturing and Its Impact on Manufacturing Performance

The influence of well executed LM programs on the company's success is considerable. Not only in the advanced industrial countries like Japan, USA and Europe but also has spread all over the world. Research by various researchers proves that for example success in China by [11], in Malaysia by [12], Thailand by [13] and also Indonesia by [14]. As a strategy developed for production performance, LM has expanded as a business practice and surpassed manufacturing to succeed in the service industry and product development operations with varying degrees of success [15]. There are still many companies have yet to implement LM tools in their manufacturing process especially in developing countries. For countries that have implemented it is still a lot of failures [16].

To measure the impact of lean practices, many authors have different criteria but convergence to one indicator known as “leanness”. Bayou and Korvin in [7] developed a model that measures leanness using lean attributes such as JIT, quality control, and Kaizen. Anvari [3] found that the most crucial components to leanness are defects, cost, lead time, and value. Cost, value, and time in order to evaluate leanness was considered by Wan and Chen in [7]. Cua et.el in [7] found that lean techniques, practices, positively and significantly affect quality, cost, flexibility and delivery. In this research, only 5 MP indicators are used, 4 indicators taken from [7] and [17] namely: 1) Quality (Q), 2) Cost (C), 3) Delivery (D), and 4) Flexibility (F) performances and 1 (one) indicator taken from [17] and [18] which is eliminating waste.

3. Research Methodology

3.1. Subjects and Objects of the Research

This research has been conducted at industrial centre in Jabotabek and Karawang. The number of medium and large industries in Jabotabek and Karawang area per 2016 is as many as 9,445 companies (kemenperin.go.id, 2016). Assuming if the LM has implemented 5%, then the number of population is 472 companies. 50 questionnaires have been taken from 15 companies or 3.2 % of the population. From 50 items only 32 were responded and only 30 items were suitable to be processed.

3.2. Research steps

In order to achieve the objectives of this study and to get a good and valid result, a series of research activities was systematically constructed. These research activities may be explained as follow:

i. Identifying for LM tools and MP indicators according to previous research (based on literature review).
ii. Generating a questionnaire to measure variables and conducting pilot study (n=100)
iii. Formulating the models (CFA models and Structural Model) using SEM tools.
iv. Data processing using Smart-PLS
v. Analysing and comparing the results through SEM standard values.
vi. Making conclusion, documentation and publication.

4. Results and Discussion

4.1. Results

4.1.1. Level of implementation of LM tools in Indonesian manufacturing industry

In general, the implementation of LM tools were good enough since almost all indicators have a high average value (above 4.0) with only 1 value below 4 for LM tool #4 with an average value of 3.96 is still considered to be quiet good because its value is very close to 4. See Table. 1 for details:

Table 1. Descriptive Statistics for LM Tools

	N	Minimum	Maximum	Mean	Std. Deviation
LMtool#1	25	3.00	5.00	4.2400	.72342
LMtool#2	25	3.00	5.00	4.0800	.90921
LMtool#3	25	3.00	5.00	4.2800	.73711
LMtool#4	25	3.00	5.00	3.9600	.73485
LMtool#5	25	3.00	5.00	4.0400	.88882
LMtool#6	25	2.00	5.00	4.1200	1.12990
LMtool#7	25	2.00	5.00	4.0000	1.11803
LMtool#8	25	2.00	5.00	4.2000	1.11803
Valid N	25				

The collected data is then processed using Smart-PLS 3.0 to perform confirmatory factors analysis to discover the indicators that were valid and reliable to represent the construct variable.

4.1.2. Outer Model Evaluation (Indicators validation)

Outer models as part of Structural Equation Modeling (SEM) specialize in the relationship between the latent variables (constructs) with their respective indicators, or in other words, the outer model illustrates how the relationship of each indicator with its latent variables. This relationship was observed by looking at the value of reliability and validity of variable research variables or also called the CFA (Confirmatory Factor Analysis) method.

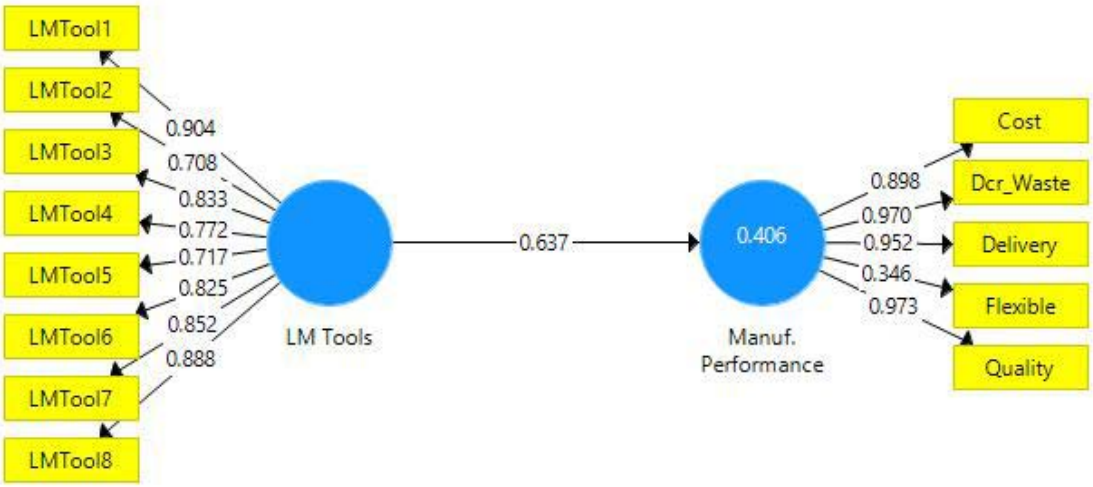


Figure 2. Outer Model for LM tools and Manufacturing Performance

From the outer image of the model it is seen that for the LM tools indicator everything is Valid because it has loading factor greater than 0.70. As for performance, manufacturing indicator there was one invalid indicator that is "Flexible" because it has a loading factor value below 0.70 that is 0.346. This is in accordance with the criteria set by Ghozali in [19] that the indicator is considered Valid representing the construct variable if it has a loading factor value greater than 0.70 for the confirmatory analysis.

Table 2. LM Indicators/Tools

No.	Indicators	Loading factor	Conclusion
1.	Tool 1: Cellular Manufacturing	0.904	Valid
2.	Tool 2: Standardized Work	0.704	Valid
3.	Tool 3: Just in Time and SMED	0.833	Valid
4.	Tool 4: Continuous Improvement	0.772	Valid
5.	Tool 5: Production Smoothing	0.717	Valid
6.	Tool 6: Value Stream Mapping	0.825	Valid
7.	Tool 7: Statistical Process Control	0.852	Valid
8.	Tool 8: Supplier Involvement	0.888	Valid

Table3. Manuf. Performance Indicators

Indicators	Loading factors	Conclusion
1. Quality	0.973	Valid
2. Cost	0.898	Valid
3. Delivery	0.952	Valid
4. Flexibility	0.346	Not Valid
5. Decrease Waste	0.970	Valid

In addition to the loading factor value, to see the validity of the constructor indicator must be seen also the value of AVE obtained value as follows:

Table 4. Average Variance Extracted

	LM Tools	Manuf. Performance
AVE	0.665	0.764

From AVE value above shows that all the construct indicator for LM Tools and Manufacturing Performance are Valid because it has AVE value greater than 0.5 that is 0.665 and 0.764.

In addition to the validity test, the measurement model is also done to test the reliability of the construct. Test Reliability is performed to prove the accuracy, consistency and accuracy of the instrument in measuring the constructs. In this research, Reliability measurements use two ways: Cronbach's Alpha and Composite Reliability where in PLS-SEM, the standard values for both are above 0.70 (Ghozali, in [20]. Although for exploratory research, a value of 0.60 is still allowed [21]. The values are as follows:

Table 5. Construct Reliability

	Composite Reliability (CR)	**Cronbach's Alpha (CA)**
Manuf. Performance	0.931	0.889
LM Tools	0.940	0.930

From Table 5 above, it appears that both Cronbach's Alpha and Composite Reliability values are both above 0.70 so that the model is considered Reliable. Because the model is Valid and Reliable then further analysis can be done that is to see the structural relationship.

4.1.3. Evaluation of Structural Equation Modeling (Inner Model)

According to Chin and Hair et al. in [21], the evaluation of the inner model in the PLS analysis consists of the t-value test and the calculation of R^2 endogenous latent variables. At 95% confidence level, exogenous variables significantly influence endogenous variables if they have p-value <0,05 and T-value > 1.96. The R^2 value of 0.67 (67%) indicates that the model falls within the good category. Chin and Hair et al in [21].

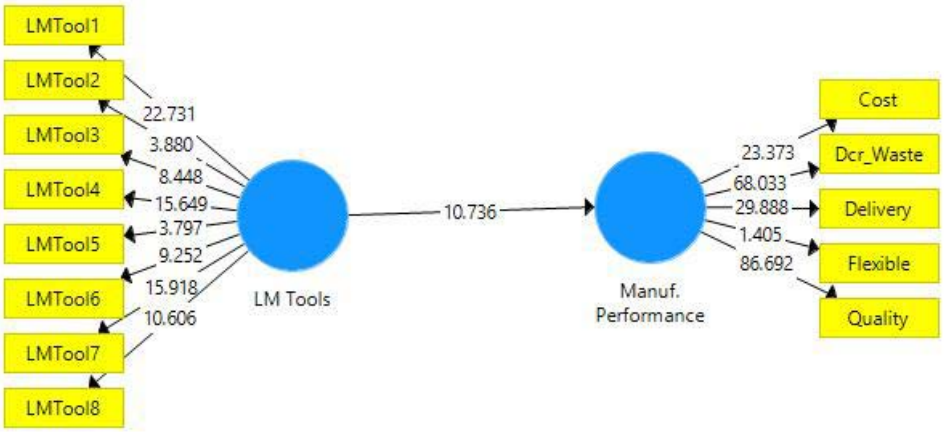


Figure 3. Bootstrapping for LM tools and Manufacturing Performance

Figure.3 illustrates how the effect of LM tools implementation on manufacturing performance (MP). At 95% confidence level, LM tools variable has t-value of 10.74 and p value = 0.00 (<0.05) means LM tools significantly influence MP. It is also seen that all of the latent variable indicators both exogenous and endogenous significantly related to latent variables because all T> 1.96 and p <0.05. T
The values of t, p and standard deviations for construct variables are presented in Table 6.

Table 6. Hasil Uji Signifikansi Model 1

Variabel konstruk	**Standar deviasi**	**t-statistik**	***p-values***
LM Tools ⟶ *Manuf. Performance*	0,059	10,74	0,000

The next stage is to evaluate the structural model (inner model) through the calculation of R^2 value of the endogenous variable (figure 4). Figure 4 shows that the value of R^2 is 0.406 or approximately 40.6%. The variation of MP is affected by LM tools and 59.4% is influenced by variations of other variables besides LM tools. According to [21], the R^2 value of 40.6% indicates the ability of exogenous variables (LM tools) fair enough to influence the variation of endogenous variables (MP) in other word the model is considered moderate.

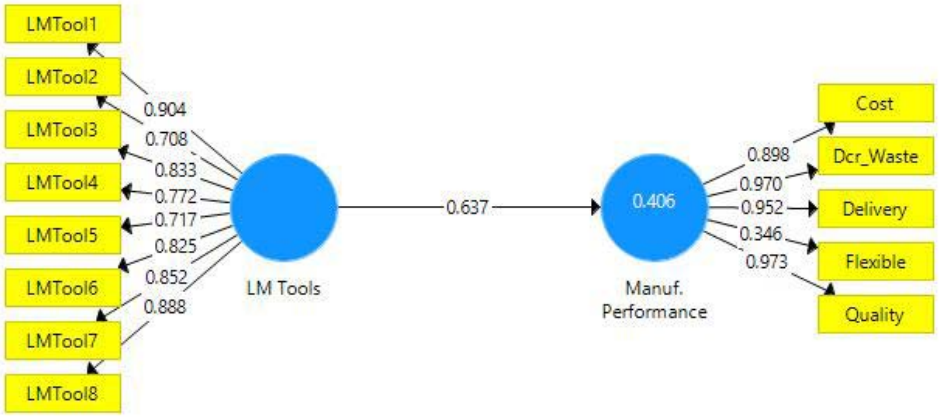


Figure 4. Inner Model for LM tools and Manufacturing Performance

Table 7. Path coefficient

	MP All
LM Tools	R = 0.637
	R Square
MP All	0.406

The relationship between LM tools with MP looks Positive and Moderate based on Path Coefficient (R value) of 0.791 and R^2 = 40.6%. This is in line with previous studies such as [13], [17] and [18] which stated that there is a strong and positive relationship between LM implementation and manufacturing performance. From the R square value can be interpreted that 40.6% MP variability can be explained by the LM tools construct variable, while the other 59.4% by unrelated variables.

4.1.4. Goodness of Fit Test

The goodness of fit test of inner model in this study used the value of SRMR, d_ULS, Chi-Square, and NFI, with the criteria of cut off values determined by [22]. From several criteria of goodness of fit test scores (table 8), it can be seen that inner model can be accepted as a good model because it have all 4 corresponding cut off values of 4 specified values.

Table 8. Test Result of Goodness of Fit Model Effect of LM Tools Implementation on MP

Goodness of Fit Index	***Saturated Model***	***Estimated Model***	***Cut off value***
SRMR	0.104	0.104	0,08 - 0,105
d_ULS	1.882	1.882	>0,05
Chi-Square	1,465.85	1,465.85	As much as possible
NFI	0.88	0.88	0,7 – 1,0

4.2 Discussion

From the results above, the implementation of all LM tools (8 tools) in Indonesian manufacturing industries was considered good enough and contributes significantly to the enhancement of MP. However, in order to achieve expected benefits from the implementation, the LM tools should be

implemented holistically instead of piecemeal adoption or separately because all the tools are inter-dependent. This result is in accordance with the research conducted by [14] who said that the implementation of 8 tools / principles of LM in Indonesia manufacturing industries is good enough and positively affect the improvement of business performance. Several research also support this result, such as [2], [18] and [23]. [18] argued, bundles of LM tools depict a high inter-correlation and inseparable features among them that give LM its unique character and superior ability to achieve multiple performance goals.

In addition to the above research, several other studies that support the positive influence of particular LM tools on manufacturing performance are: [20], [24], [25], [26], [27] and [28]. Adesta [20], [24], [25], [26] conducted research in Indonesia, where [27], have conducted research in Malaysia and [28] in Thailand. [20] revealed that Total Productive Maintenance (TPM) play a very critical role for the successful LM implementation and have a strong and positive impact to manufacturing performance. [26] and [24] found that VSM tool is the most powerful LM tool in reducing waste. Reduced cycle time, lead time and non-value added time. While [25] assumes that lean supply chain, VSM, value stream analysis (Valsat) and customer involvement have a major impact on reducing value and non-value added time and improving supply chain efficiency.

[27] from Malaysia have assessed the effect of the implementation of 2 tools LM namely Kobetsu Kaizen (Continuous Improvement) and VSM to manufacturing performance. It turns out to have a positive effect in improving performance and decreasing waste in the form of decreasing reject products, material leakage, lead-time, non-value-added time, set-up time and number of required operators. Also [28] from Thailand who found the result of application of various LM tools have positive effect on productivity improvement and reduction of process time (non-value added activities decrease and reduction of overtime).

5. Conclusion

In summary, it may be concluded that the implementation LM tools (8 tools) in Indonesia manufacturing industries were sufficiently good. All tools were valid and significant to represent LM tools and strategy. From structural model can also be concluded that the relationship of LM tools and MP is Positive and at Moderate level, where 40.6% variability of MP can be explained by LM tools and the rest influenced by other factors. Last but not the least, this study answer the question that the implementation of LM is also running well enough in the developing countries and not only in the developed countries.

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