Measurement Instrument for Lean Manufacturing

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Abstract

The present paper is aimed to provide a comprehensive measurement instrument for lean manufacturing, because there is no single agreement on how to measure the level of implementation of lean manufacturing. The measurement instrument has been generated in the present study based through an extensive literature review. The instrument has been tested for validity and reliability by using 49 samples of large and discrete part industries in Indonesia. It was concluded that the measurement items are valid and reliable.

Keywords: lean manufacturing, measurement instrument, holistic implementation, Indonesia

1. Research Background

Citing the statement of Heizer and Render (2008) and Russell and Taylor III (2008), there was a little difference between TPS, JIT and lean manufacturing (LM) in practice, as a result, the terms TPS, JIT and LM were often used interchangeably. Slack, Chambers, and Johnston (2010) also revealed the similarity between LM and JIT. Arif-Uz-Zaman and Nazmul Ahsan (2014) stated that the foundation of lean manufacturing is TPS, which is based on JIT. Schonberger (2007) stated that the practices under LM were same as JIT. In a nutshell, The concept and practices of lean manufacturing, TPS, and JIT are similar (Heizer & Render, 2008). Thus, subsequently, the term LM will be used in this paper to cover all the related approaches and techniques, due to the similarity of the three terminologies.

Despite the claim from Heizer and Render (2008), Russell and Taylor III (2008), Schonberger (2007), and Slack et al. (2010) as mentioned above, numerous practitioners and academicians, such asAbdallah and Matsui (2007), Bartezzaghi and Turco (1989), Callen, Fader, and Krinsky (2000), Chen and Tan (2011), Mackelprang and Nair (2010), Shah and Ward (2007), and Pettersen (2009)noted that there was no longer a single agreement on a clear definition and practices of LM. The definitions and practices used under LM varied widely based on the authors' background. Ahmad, Schroeder, and Sinha (2003) also described that LM as a complex subject was usually summarized in very brief statements, sometimes the required information being omitted, in such a way it caused confusion in implementing the concept. Furthermore, Ramarapu, Mehra, and Frolick (1995) and Pettersen (2009) stated that the lack of consensus regarding the interpretation of LM was a major problem in the literature. The disagreement has become one of the reasons why LM succeeded in one plant and failed in another (Ahmad et al., 2003; Bartezzaghi & Turco, 1989; Callen et al., 2000; Fullerton & Wempe, 2009; Hadid & Mansouri, 2014). Moreover, Pettersen (2009)had comprehensively summarized the possible effects introduced by this issue. He revealed that this issue may lead to several disadvantages as below:

a. Communication difficulties.
b. Complicate education in the subject.
c. Researching the subject will be difficult.
d. Difficulties in defining overall goals of the concept.
e. Hard to claim about the effects introduced by LM.

f. Difficulties in determining whether particular changes made within an organization are consistent with the LM or not.
g. Difficulties in quantifying and evaluating the effectiveness of LM implementation.

As the concept widened in scope and focus, it is essential to produce a thorough measurement instrument to assess the level of LM implementation. The present study is attempting to provide a comprehensive measure based on an extensive literature review. Furthermore, the measurement items are tested for construct validity and reliability. On eventually, association among the LM practices will be assessed.

2. Literature Review

An extensive literature review indicated that there were several definition produced by numerous authors. Examples of definition of LM from several well-known literatures are as follows:

a. LM is a philosophy, approach, technique and integrated management system that synergistically addressed improvement of operations performance in the production system (Bartezzaghi & Turco, 1989).
b. LM is a manufacturing philosophy, which involves having the right items with right quality and quantity in the right place and at the right time, in such a way it is related to higher productivity, higher quality, lower costs, and higher profits (Cheng & Podolsky, 1993).
c. LM is a management philosophy aimed at eliminating non value added activities from all aspects of manufacturing and its related activities. It refers to producing as required, when it is required, in the amount required(Shingo, 1985).
d. LM is an integrated problem solving approach pointed at cultivating quality and facilitating timeliness in supply, production and distribution (Davy, White, Merritt, & Gritzmacher, 1992)
e. LM is an holistic approach to continuous improvement based on the concept of eliminating non value added activities in a manufacturing process (Sakakibara, Flynn, Schroeder, & Morris, 1997).

Based on the above definitions, although definitions of LM are continuously expanding, there was a consensus among academicians and practitioners that the basic underlying objective of LM is to eliminate the waste (non-value added activities), extending along its entire supply chain networks, within and across companies. As originally presented by Ohno (1988), there are seven types of waste, which LM aims to eliminate. They are over productions, unnecessary inventory, defects, unnecessary movement, over processing, waiting (delay) time, and transportation. Hence, Summarizing from the definitions above, the present study defines LM as *"an approach synergistically addressing to eliminate waste in a production system."*

Nowadays, the concept of LM is continually blossoming out as well as expanding the scope and focus. A review on several key studies indicated that although a large body of empirical studies, for example Chen and Tan (2011); Furlan, Dal Pont, and Vinelli (2011a); Furlan, Vinelli, and Dal Pont (2011b); Hofer, Eroglu, and Hofer (2012); Mackelprang and Nair (2010) and Mazanai (2012), highlighted the positive relationship between LM and performance, a few studies found different findings (such as Sakakibara et al. (1997), Ahmad, Mehra, and Pletcher (2004)). The inconsistent implication of LM on companies' performance implied that methodological issue (i.e., constructs that may not have a practically valid identity) seems likely to contribute to the variation of LM effects resulted from a study. Related to the methodological issue; different authors offered different set of LM practices. The practices of LM have been diverse based on the author's experience and the different assortment of features (Ramarapu et al., 1995). Sometimes, definition and practices of LM have often been interpreted quite loosely. Even, Ramarapu *et al.* (1995), Mehra and Inman (1992), and Fullerton and Wempe (2009)stated that the wide-ranging nature of the interpretation of LM in literature seems to be the major cause of confusions.

For LM to perform well in eliminating waste, some essential practices must be well defined and established. The success of LM depends on implementation of the practices (Ramarapu et al., 1995). Ahmad *et al.* (2003), Belekoukias, Garza-Reyes, and Kumar (2014), Chen and Tan (2011), Mackelprang and Nair (2010), and Shah and Ward (2007) revealed that although many studies have been addressed to identify the fundamental practices of LM, there was still no single consensus among scholars concerning the significance of each LM practices. The absence of the consensus was the main reason why practitioners and academicians offer different set of practices to cover the LM concept.

As the concept that is constantly evolving and widening, it is not easy to formulate the consistent and integrative practices of LM. Reviewing prior literatures, several authors strongly agreed that the potential benefits of LM cannot be fully realized until all the practices are implemented integrally and holistically (Cheng & Podolsky, 1993; Furlan *et al.*, 2011b; Singh & Ahuja, 2014). Even, Shah and Ward (2007), Furlan et al. (2011a), and Nawanir, Lim, and Othman (2013) noted that LM must be applied as a total system. Piecemeal adoption will not be successful to convey a company to an outstanding position. Borrowing the terms used by Ramarapu et al. (1995), piecemeal adoption of LM will only create *"island of lean manufacturing"* but will not significantly contribute to the company-wide improvement that increase its competitiveness. This idea may have motivated several scholars in LM, such as Shah and Ward (2003, 2007), Furlan *et al.* (2011a); Furlan *et al.* (2011b), and Dal Pont, Furlan, and Vinelli (2008) to formulate the concept of bundles or complementarity among LM practices.

Through an in-depth literature review, the present study attempts to produce the bundle of LM practices those have been previously tested in a number of prior studies as effective practices to enhance the better companies' performance. Several prior conceptual and empirical studies have been used to identify and develop LM practices by considering its significant impact on performance. The practices of LM are listed in Table 1. In selecting the practices, the common practices from the previous studies were assembled by regrouping various LM related practices into nine, namely flexible resources, cellular layouts, kanban/pull system, small lots production, quick setups, uniform production level, quality control, total productive maintenance, and supplier networks. Even though the present study does not comprise some of the LM practices deliberated in the literature as separated elements, many were integrated into allied practices.

Table 1: Practices of Lean Manufacturing

Lean Practices	**Literatures Supported**
Flexible resources	
Training for multiple tasks	1, 3, 4, 7, 9, 10, 13, 19, 20, 22, 23, 24
Multi-skilled employees	2, 4, 5, 6, 7, 8, 23, 24, 25
Multi-functional machines	2, 9, 11, 24
Cellular layouts	
Cellular manufacturing /JIT Layout	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 24, 25
Pull system/Kanban	
Kanban	1, 2, 4, 5, 7, 8, 10, 11, 12, 13, 17, 18, 19, 20, 21, 22, 23, 24, 25
Pull system	1, 6, 10, 11, 14, 18, 20, 23, 24, 25
Small lot production	
Small lot production/Lot size reduction	1, 2, 3, 6, 9, 11, 13, 17, 18, 21, 22, 23, 24, 25
Quick setups	
Setup time reduction	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25
Training for quick setup	3, 4, 10, 11, 12, 13, 16, 19, 20, 21
Uniform production level	
Daily schedule adherence (JIT scheduling)	1, 2, 7, 11, 13, 14, 18, 21, 22, 23, 24, 25
Repetitive production	2, 4, 11, 12, 14, 18, 21, 24, 25
Uniform work load	2, 4, 5, 8, 11, 12, 23, 24, 25
Quality Control	
Quality at the source	2, 3, 4, 5, 8, 10, 13, 16, 17, 22, 23, 24, 25
Statistical process control	2, 3, 4, 5, 8, 10, 13, 19, 22, 24
Training for quality improvement	3, 4, 9, 10, 13, 19, 20, 21
Quality circle	2, 3, 4, 20, 24
Total Productive Maintenance	
Preventive maintenance	1, 2, 3, 4, 6, 9, 10, 12, 17, 18, 19, 23, 24, 25
Training for maintenance activities	3, 4, 10, 13, 19, 20, 21
Supplier Networks/JIT Purchasing	
JIT delivery by suppliers	1, 2, 4, 5, 7, 8, 9, 10, 11, 12, 13, 18, 19, 21, 22, 23, 24, 25
Supplier involvement	2, 3, 4, 5, 7, 8, 9, 10, 15, 21, 23, 24
Supplier development program	2, 3, 4, 5, 8, 9, 10, 15, 23, 24
Long term agreement with supplier	2, 3, 4, 5, 8, 9, 10, 11, 23, 24

Note. 1 = Sakakibara *et al.* (1993); 2 = Lee and Paek (1995); 3 = Ramarapu *et al.* (1995); 4 = Callen *et al.* (2000); 5 = Fullerton and McWatters (2001); 6 = Shah and Ward (2003); 7 = Ahmad *et al.* (2003); 8 = Fullerton, McWatters, and Fawson (2003); 9 = Kannan and Tan (2005); 10 = Shah and Ward (2007); 11 = Matsui (2007); 12 = Abdallah and Matsui (2007); 13 = Dal Pont *et al.* (2008); 14 = Hallgren and Olhager (2009); 15 = Jayaram, Vickery, and Dröge (2008); 16 = Fullerton and Wempe (2009); 17 = Rahman, Laosirihongthong, and Sohal (2010); 18 = Mackelprang and Nair (2010); 19 = Taj and Morosan (2011); 20 = Yang, Hong, and Modi (2011); 21 = Furlan *et al.* (2011a); 22 = Furlan *et al.* (2011b); 23 = Chen and Tan (2011); 24 = Nawanir *et al.* (2013); 25 = Belekoukias *et al.* (2014).

3. *Methodology*

3.1. Measurement

Appendix A provides the sample items used to measure the company's current implementation of the LM practices. Each measurement item was addressed to measure a specific content that was adapted from several recent literatures. The measurements are performed by using the perceptual scale. Six-point Likert scale was used in this study to measure LM practices.Krosnick and Fabrigar (1991) postulated that the five, six, and seven-point Likert scales are more valid and reliable rather than shorter and longer scales. The six-point Likert scale was chosen in the present study. It was rationalized by Krosnick (1991) who suggested preventing the respondents from answering a neutral point, an ambiguous response or a midpoint, because it will affect to the decreasing of measurement quality (i.e., construct validity and reliability). Hence, the use of six-point scale helps to increase construct validity and reliability of instrument by reducing social desirability bias of answering in a neural point. More importantly, as suggested by Krosnick (1999) through his empirical study entitled "*maximizing questionnaire quality*", data quality is better if all the scale points are verbally labeled rather than when only some are. In addition, respondent are more satisfied and confident to answer when the scale points are verbally labeled. In the present study, the following six-point Likert scale was used, strongly disagree (1); disagree (2); slightly disagree (3); slightly agree (4) agree (5); and strongly agree (6).

3.2. Content Validity

Once the instrument has been developed, the instrument as a whole were validated and evaluated before the final administration (de Vaus, 2002). To ensure and further enhance the content validity, readability, and brevity, the instrument has been pre-tested and reviewed by a number of academicians and practitioners who are specialist in operations management, especially lean manufacturing. Experts consisting of five academicians and three practitioners were involved. The pre-test alerts the researcher to any potential problems that may be caused by the instrument. It was consultation and structured interviews with the respondents to examine whether there are any questions that need to be included or excluded as measurement; whether the content of the instrument is sufficient; whether the right questions being asked; and whether the questions are easy to understand. The feedbacks from the respondents were used to develop a better instrument through clarifying the wordings, and some measurement items are added, discarded, or modified.

3.3. Data Collection

Data collection has been conducted started from the mid of August until the mid of September 2012 in large and discrete process industries in Indonesia by choosing the commonly selected industries in the LM past studies, for instance, textiles; wearing apparel; tanning and dressing of leather; wood and products of wood except furniture and plaiting materials; machinery and equipment; electrical machinery and apparatus; radio, television and communication equipment and apparatus; medical, precision and optical instruments, watches and clocks; motor vehicles, trailers and semi-trailers; other transport equipment; and furniture. More than 50 respondents (i.e., manufacturing director, head of department, manager, and LM implementer), which were selected randomly, involved in the study, however only 49 cases were usable for construct validity and reliability analysis because of too many missing values and inappropriate respondent.

4. *Finding and Discussion*

4.1. Construct Validity and Reliability

After amending the instruments based the feedback obtained from the pre-test, construct validity and reliability were assessed. The construct validity in terms of construct unidimensionality is subsequently tested by using the software package of SPSS 19. Validity is a hierarchy procedure to ensure that whatever which is concluded from a research can be shared confidently (Garver & Mentzer, 1999). Construct unidimensionality is defined as the existence of one construct underlying a set of items (Anderson & Gerbing, 1988), in other words, construct unidimensionality refers to the degree to which the measurement items represent one and only one underlying construct (Garver & Mentzer, 1999). Factor analysis was recognized as the most powerful method to assess the construct unidimensionality (Anderson & Gerbing, 1988; Shah & Goldstein, 2006). Due to the sample size for the study was small, as widely applied by several researchers (Agus & Hajinoor, 2012; Lim, 2003; Nawanir *et al.*, 2013; Sakakibara, Flynn, & Schroeder, 1993), the factor analysis has been applied for each construct separately.

The suggested sample size for a stable factor analysis is roughly between 5 and 10 cases for each item(Hair, Black, Babin, & Anderson, 2010). Due to the largest number of measurement item for a construct is 8, the sample size, which is greater than 40, is sufficient.

The summary of factor analysis result is given in Table 2. The detail of the results is exhibited in Appendix A. For each construct, results of the factor analysis revealed one factor with eigenvalue greater than one. There was no item in each construct that was extracted into more than one factor. The table displays that factor loadings for all constructs range between0.648and 0.989.Most of them are greater than 0.70. The lowest factor loading of the present study is considered marginally acceptable and the item is then retained. Besides the factor loadings, communalities demonstrating the amount of variance accounted for by factor solution for each items (Hair *et al.*, 2010; Tabachnick & Fidell, 2007) range between 0.420 and 0.977. Although there are some items with communality value less than 0.50 (i.e., one item in both quality control and total productive maintenance), the factor loading for the two items are high; 0.648 and 0.668 respectively. Hence, the items are remained because of high factor loading.

The Kaiser-Meyer-Olkin (KMO) measure tests whether measurement items are sufficient for each factor (Leech, Barrett, & Morgan, 2005). Based on Table 2, all the KMO values resulted from each factor analyses are greater than 0.7 and considered acceptable. Furthermore, to provide the conviction of conducting factor analysis, the Bartlett's tests of sphericity were conducted for each construct to test whether measurement items are highly correlated. Agree with Leech *et al.* (2005), the Bartlett's tests of each construct for the present study are significant at $\alpha = 0.05$. However, according to Tabachnick and Fidell (2007), the Bartlett's tests of sphericity is dependent on number of sample, the assessment is expected to be significant with samples of considerable size, even if the correlations among the constructs are very low. They further suggested that this test is recommended only if there are fewer than five observations per measurement item. More importantly, Table 2 gives evidence that all the constructs have more than 50% of total variance explained. The cumulative percent of variance range from 60.889% to 83.916%, and thus, the variances explained by each construct are acceptable.

Due to the reliability assumes unidimensionality (Anderson & Gerbing, 1988; Garver & Mentzer, 1999), it must be initially achieved. After achieving construct unidimentionality, reliability was tested. The reliability ensures the internal consistency and stability of measurement items to measure a construct (Garver & Mentzer, 1999). Meanwhile, the Cronbach's alpha is the most widely used indicator to assessed the internal consistency (Coakes & Steed, 2007; Garver & Mentzer, 1999; Sekaran, 2003; Shah & Goldstein, 2006). The alpha value ranges between 0 and 1. The closer to 1, the better the reliability of a construct (Coakes & Steed, 2007; Sekaran, 2003). Alpha values of greater than 0.70 indicated an adequate construct reliability (Sekaran & Bougie, 2009). Table 2 shows that all the alpha values are more than 0.80. Hence, constructs reliability are achieved. Based on the construct validity and reliability tests, the instrument is valid and reliable.

Table 2: Statistical Summary of Construct Validity and Reliability

Construct	Factor Loading	Communality	KMO	Eigen Value	% Variance	α
Flexible Resources (7)	0.737 - 0.960	0.544 - 0.922	0.865	4.820	68.852	0.910
Cellular Layouts (8)	0.826 - 0.972	0.682 - 0.945	0.845	6.276	78.453	0.956
Pull System (6)	0.854 - 0.989	0.729 - 0.977	0.761	5.035	83.916	0.956
Small Lot Production (7)	0.729 - 0.965	0.532 - 0.932	0.791	5.061	72.297	0.932
Quick Setup (7)	0.739 - 0.843	0.547 - 0.711	0.811	4.262	60.889	0.884
Uniform Production Level (7)	0.709 - 0.961	0.503 - 0.924	0.787	4.558	65.118	0.898
Quality Control (8)	0.648 - 0.931	0.420 - 0.867	0.824	5.325	66.564	0.916
Total Productive Maintenance (7)	0.668 - 0.954	0.446 - 0.910	0.773	4.602	65.746	0.904
Supplier Networks (7)	0.768 - 0.967	0.589 - 0.935	0.835	5.016	71.651	0.920

Note. Number in parentheses are the number of item for each construct; α = Cronbach's alpha representing construct reliability.

4.2. Criterion-Related Validity

Criterion-related validity provides evidence about how well the score of a measure correlates with the score of other measures that theoretically should be related (Kimberlin & Winterstein, 2008). Pearson's correlation analysis was used to assess this type of validity. As expected, correlation coefficients among the LM practices are positive and significant at 0.01 level (see Table 3). This indicates strong criterion-related validity (Sekaran & Bougie, 2009).

Table 3: Pearson Correlation among the LM practices

LM Practices	1	2	3	4	5	6	7	8	9
1. Flexible resource	1								
2. Cellular layouts	.628	1							
3. Pull system	.777	.707	1						
4. Small lots production	.615	.731	.772	1					
5. Quick setup	.645	.575	.629	.563	1				
6. Uniform production level	.765	.732	.798	.629	.734	1			
7. Quality control	.724	.737	.727	.645	.767	.782	1		
8. Total productive maintenance	.745	.664	.661	.555	.797	.686	.813	1	
9. Supplier networks	.766	.553	.746	.675	.659	.697	.678	.672	1

Note. Correlations are statistically significant at the 0.01 level (2-tailed).

5. Implication of the Study

The study has identified a comprehensive and validated measurement for LM. The use of the measurement item allows future studies to investigate the level of implementation of LMmore comprehensive and accurate. Practically, the present study provided a valuable tool for academicians and practitioners to assess the level of LM implementation in their companies. It can be used to evaluate their companies quantitatively and take possible actions in order to enhance companies' performance.

6. Limitation and Suggestion for Future Research

This study is not without limitation. The small number of respondents participated in the present study seems to be a major limitation of the study. It is suggested that more respondents are required in order to provide a more accurate results. In addition, it is common in all survey-based research, it is assumed that the respondents are knowledgeable enough to answer the research instrument. Other than that, the data used in the study is based on self-reporting, although there is no common method variance as indicated by Harman's single factor test (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003), data collection from multiple respondents from one company is suggested for future studies.

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Appendix A: Sample of Measurement Items

Code	Question	Literature
Flexible Resources		
FR5	The production workers are capable of performing several different jobs.	Sakakibara et al. (1993); Russell and Taylor III (2008); Ketokivi and Schroeder (2004)
FR3	The production workers are cross-trained to perform several different jobs.	Shah and Ward (2007); Furlan et al. (2011b); Nawanir et al. (2013)
Cellular Layouts		
CL3	Layout of workstations can easily be changed depending on sequence of operations required to make the product.	Hirano (1989); Rogers (2008); Nawanir et al. (2013)
CL8	Families of products determine our factory layout.	Fullerton and Wempe (2009); Hofer et al. (2011); Krajewsky and Ritzman (2005)
Pull System		
PS2	Production at a particular workstation is performed based on the current demand of the subsequent workstation.	Koufteros et al. (1998); Olsen (2004); Shah and Ward (2007); Nawanir et al. (2013)
PS5	We use kanban system to authorize material movements.	Russell and Taylor III (2008)
Small Lot Production		
SLP5	We receive products from suppliers in small lots with frequent deliveries.	Singh, Garg, and Sharma (2010)
SLP7	We produce only in necessary quantities, no more and no less.	Russell and Taylor III (2008); Cheng and Podolsky (1993)
Quick Setups		
QS6	The production workers are trained on machines' setup activities.	Taj and Morosan (2011); Hirano (2009); Ketokivi and Schroeder (2004)
QS3	We are aggressively working on reducing machines' setup times.	Sakakibara et al. (1993); Abdallah and Matsui (2007); Shah and Ward (2007)
Uniform Production Level		
UPL1	We produce more than one product model from day to day (mixed model production).	Sakakibara et al. (1993); Russell and Taylor III (2008); Nawanir et al. (2013)
UPL6	We produce by repeating the same combination of products from day to day.	Sakakibara et al. (1993); Russell and Taylor III (2008)
Quality Control		
QC1	We use statistical techniques to reduce process variances.	Olsen (2004); Russell and Taylor III (2008); Ketokivi and Schroeder (2004)
QC8	The production workers are trained for quality improvement.	Jayaram and Ahire (1998); Cheng and Podolsky (1996)
Total Productive Maintenance		
TPM3	We have a sound system of daily maintenance to prevent the machine breakdown from occurring.	Koufteros et al. (1998); Russell and Taylor III (2008)
TPM6	Machine operators are trained to maintain their own machines.	One, Jantan, and Ramayah (2005); Moayed and Shell (2009)
Supplier Networks		
SN7	Our suppliers deliver materials to us just as it is needed (on just-in-time basis).	Abdallah and Matsui (2007); Shah and Ward (2007)
SN3	We emphasize to work together with the suppliers for mutual benefits.	Heizer and Render (2008); Nawanir et al. (2013)

Note. Please contact the corresponding author for the complete list of measurement item.