A Quantitative Approach of Leanness Assessment in Electronics Manufacturing Firms

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Abstract Lean is a concept that eliminates all waste and maximizes customer value with fewer resources needed based on the Toyota Production System. The purpose of this study is to identify lean manufacturing practices from the literature review and industrial experts, and to develop a lean assessment tool to measure the level of lean implementation in manufacturing firms. A quantitative lean assessment approach in the form of a Likert Scale questionnaire survey with a total of 19 lean practices were developed and sent to two different electronics manufacturing firms with similar processes and product range. The high values of Cronbach's Alpha which is more than 0.8 show that the questionnaire is reliable. The Two-Sample T-test was used to compare the level of lean implementation between the two companies as well as to compare the view of Top management and Executive position. The results of statistical analysis show that the average mean score for Hard Lean practice for Company A is 3.63 and for Company B is 3.05, while the mean score for Soft Lean Practice for Company A and Company B is 4.14 and 2.85, respectively. The level of lean implementation of Company A for both category of Lean Practices is significantly better than Company B. Therefore it can be concluded that Company A is having a better lean implementation compared to Company B. This study has implications for the firms as it can explore the extent of lean manufacturing implementation and to compare the leanness of departments within a firm. The limitations of the research were small sample size and lack of involvement from the executive level. For future study, the open-ended interview can be integrated into the research and the contents of the questionnaire can be modified based on firm types.

Keywords Lean manufacturing · Leanness · Likert scale · Cronbach's alpha · T-test

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1 Introduction

Lean is a concept that eliminates all waste and maximizes customer value with fewer resources needed. Lean is a philosophy based on Toyota Production System (TPS). The ultimate goal of lean is to provide a perfect value of products or services to the customer with zero waste in a continuous flow. There are seven types of waste which are inventory, transportation, waiting, motion, process, defects, and over-production. Lean is a way of thinking to eliminate all kinds of waste along the value streams. For instance, a manufacturing process is modified so that less space, less cost, less time, less human resources and fewer defects can be achieved while the quality of the products can be maintained or improved. There is some misunderstanding that lean can only be applied in manufacturing, however lean can actually be implemented in every business and every process.

Nevertheless, a transition to lean is difficult and it is a long-term journey since a company must build a culture with learning and continuous improvement in order to adapt to the lean implementation [1]. The commitment and teamwork of employees from every level of an organization along the lean journey are needed in order to implement lean successfully. The examples of a global company that implementing lean successfully are Toyota, Intel and Nike. Moreover, the successful implementation of lean is not only depends on the involvement, commitment and teamwork from the shop floor employees, but the top management involvement is crucial to plan, motivate, train and lead the employees [2]. Therefore, this study will focused on the leanness assessment for the top management and executive level.

In this modern era, organizations from every firm and industry have realized the benefits of lean in improving their organizations and started to implement lean. Various lean tools or lean practice can be adopted to make a change in an organization depends on the situation and needs of the organization. However, some of the organizations just simply implement lean without an assessment method to evaluate the progress of the lean journey. The level of lean implementation can actually be assessed or evaluated through the leanness assessment. Therefore the objectives of this study is threefold which is to identify the lean practices based from literature review and industrial expert, to develop a leanness assessment method, and to evaluate and measure the leanness at two electronics manufacturing firms.

2 Methodology

The study will focus on the lean practices as an assessment indicators that are found from the literature review [3–8] and involvement from the industrial expert. The leanness assessment was in the form of Likert Scale structured questionnaire that contains two sections. The assessment was distributed to the employees of two different position (Top Management and Executive) at two different companies with a similar process and product range. The questionnaire mainly consists of two sections. In

Section A, 12 hard lean practices adopted in the company can be investigated. In Section B, there are 7 soft lean practices will be used to evaluate the leanness in that company. The following Hard Lean and Soft Lean practices will be involved in Section A and Section B, respectively;

Section A: Hard Lean Practices (5S, JIT, TPM, Kanban System, VSM, Kaizen, SMED, Poka Yoke, Cellular Manufacturing, Jidoka, Heijunka, Standardization).
Section B: Soft Lean Practices (Employee Awareness, Quality of Professional Development, Production Control, Supplier Partnership, Customer Involvement, Quality of Leadership, Monitoring of Lean Progress).

Prior distributing the questionnaires to the respective respondent, experts from industry were assigned to verify the questionnaires. This is to ensure that the questionnaires are valid and meet the objectives of the study. Likert Scale is a type of scale that commonly used in research that involve Survey questionnaires. A Likert Scale Questions is a set of question that contains the responses from several Likert-type items. Therefore, the combination of Likert-type items can provide a quantitative measure of a characteristic or level. A typical Likert Scale will be scored from 1 to 5 so that the respondents can rate how they agree or disagree with a certain statement [9, 10]. In this study, a typical 5-level Likert Scale is used: 1. Strongly Disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly Agree. Most researchers develop several Likert-type items and combine them into a "survey scale," in order to calculate a total score or mean score for the scale items. For unique Likert-type items, modes, medians and frequencies are the suitable tools to use. For Likert Scale that used to measure particular traits, mean and standard deviations can be used to describe the scale [11].

Before the analysis, Cronbach's alpha was calculated to measure the reliability of the collected data. It is imperative to measure the internal consistency of the Likert Scale Questionnaire [12]. In other words, Cronbach's alpha measures how closely related a set of items are as a group. A Cronbach's alpha normally ranges from 0 to 1. A higher alpha means that the scale is highly reliable. Values above 0.7 are acceptable. Next, a statistical analysis was carried out to analyse and interpret the results of the leanness assessment. The statistical method was used to compare the data using Two-Sample T-test to compare the levels of lean implementation between the two companies. Comparison between the Top Management and Executive level will also be done to understand their perception towards lean implementation. Before the Two-Sample Test was conducted, the Levene Test was first performed to confirm whether the variance of the data was the same or different. All the analysis were carried out using Minitab to measure the level of lean implementation of the companies.

The Two-Sample T-test for the two companies is;

Ho: $\mu A \leq \mu B$.
Ha: $\mu A > \mu B$.

3 Results and Discussion

The leanness assessment has been done at two different electronics manufacturing firms namely Company A and Company B. Company A is a global manufacturer of electronic components. The products include sensors, resistors, magnetics, semiconductors, and connectors. Company A originated from UK and now employing staff across 31 locations. The general manager of company A claimed that they are implementing a high level of lean manufacturing in their company. In company A, they believe that there is an 8th waste, which is Talents since the underutilization of human resources will cause waste too. Talent workers must be placed at the correct position in order to do what they good at. In Company A, there is a "Be Lean" Training Room for training purpose. There are 12 Lean Practices that implemented in Company A, which is Cell Design, Pull System, Visual Management, Quick Changeover, TPM, Error Proofing, VSM, Standard Work, Six Sigma, Voice of Customer (VOC), Quality Control Process Charting (QCPC) and 5S. Due to the high level of lean implementation, Company A gained "Be Lean" Excellence Award 16 and Best Performance Site 19 within their organization. On the other hand, Company B is a global manufacturer of advanced magnetics materials and other related products. The products include permanent magnets, crystalline alloys and rapidly solidified alloys. Company B involves in various field and industry, such as medical technology, renewable energy, automotive and hand watch making. Company B is originated from Germany and currently applying Six Sigma in their company. The number of respondents in each company is shown in Table 1.

From the Table 2, Cronbach's Alpha of each Scale for Company A and Company B are more than 0.8. Therefore, it can be said that the internal consistency of each scale is good and the scale items are closely related as a group. If the Alpha value is less than 0.5, the internal consistency is unacceptable.

Table 3 shows the comparison of Mean score and P-value between Company A and Company B in Section A of the Questionnaires (Hard Lean Practices). Since the P-value of Levene Test is 0.236, the variance of all the score is the same. The results of the Two-Sample T-Test indicates that the implementation of TPM, Kanban System, VSM, SMED, Poka Yoke, Cellular Manufacturing, Jidoka and Heijunka in Company A is significantly better than Company B. If the P-value of Two-Sample T-test is smaller than $\alpha = 0.05$, *Ha* is accepted. Therefore, there is statistical significance to say that the implementation of that particular lean tools or practices of Company A is better than Company B. The average mean score for Hard Lean practice for

Table 1 Number of respondent

	Company A	Company B	Total	Percentage (%)
Top management	6	4	10	31.25
Executive	15	7	22	68.75
Total	21	11	32	100

Table 2 Cronbach's Alpha of each scale

Scales	Cronbach's Alpha
Tools and practices	0.95
Employee awareness	0.87
Quality of professional development	0.92
Production control	0.81
Supplier partnership	0.8
Customer involvement	0.82
Quality of leadership	0.86
Monitoring lean progress	0.9

Table 3 Comparison of mean score and P-value for Company A and Company B in Section A

	Hard lean practices	Mean score (Company A)	Mean score (Company B)	P-value
A1	5S	3.62	3.45	0.242
A2	JIT	3.62	3.27	0.085
A3	TPM	3.67	3	0.025*
A4	Kanban system	3.37	2.67	0.019*
A5	VSM	3.86	3.27	0.047*
A6	Kaizen	3.86	3.91	0.565
A7	SMED	3.17	1.86	0.000*
A8	Poka yoke	3.81	3.45	0.037*
A9	Cellular manufacturing	3.9	2.82	0.001*
A10	Jidoka	3.47	3	0.045*
A11	Heijunka	3.29	2.13	0.004*
A12	Standardization	3.86	3.73	0.282

* implies significant where P-value less than 0.05

Company A and Company B is 3.63 and 3.05, respectively, implies that Company A is better implementation of Hard Lean Practice compared to Company B.

In section B, the 7 categories of Soft Lean Practices will be compared between Company A and Company B based on the mean score of each category by using Two-Sample T-Test as shown in Table 4. Since the P-value of Levene Test is 0.509, *Ha* is accepted. The variance of all the score is the same. From Table 4, all the P-value of Two-Sample T-test is lower than $\alpha = 0.05$, so *Ha* is accepted. Therefore, the level of lean implementation of Company A in each category of Soft Lean Practices is significantly better than Company B. The average mean score for Soft Lean practice for Company A and Company B is 4.14 and 2.85, respectively, implies that Company A is better implementation of Soft Lean Practice compared to Company B.

On the other hand Table 5 shows the results of the Two-Sample T-Test between Top management and Executive position. In this case, there is significantly difference in how Top Management and Executive view the application of Heijunka in

Table 4 Comparison of mean score and P-value for Company A and Company B in Section B

	Soft lean practices	Mean score (Company A)	Mean score (Company B)	P-value
B1	Employee awareness	4.3	2.59	0.000*
B2	Quality of professional development	4.22	2.55	0.000*
B3	Production control	4.25	3.06	0.000*
B4	Supplier partnership	3.44	2.21	0.000*
B5	Customer involvement	4.17	3.17	0.000*
B6	Quality of leadership	4.13	3.28	0.002*
B7	Monitoring lean progress	4.46	3.09	0.000*

* implies significant where P-value less than 0.05

Table 5 Comparison of mean score and P-value for top management and executive in Section A for both companies

	Hard lean practices	Company A			Company B		
		Mean score (top management)	Mean score (executive)	P-value	Mean score (top management)	Mean score (executive)	P-value
A1	5S	3.83	3.53	0.304	3.75	3.00	0.200
A2	JIT	3.50	3.67	0.572	3.75	3.00	0.134
A3	TPM	4.00	3.53	0.302	3.25	2.80	0.197
A4	Kanban system	3.50	3.27	0.676	2.50	2.80	0.407
A5	VSM	4.50	3.60	0.050*	3.25	3.29	0.947
A6	Kaizen	4.50	3.60	0.050*	4.00	3.86	0.695
A7	SMED	3.33	3.07	0.496	2.50	1.60	0.266
A8	Poka yoke	4.00	3.73	0.292	3.75	3.29	0.166
A9	Cellular manufacturing	4.00	3.87	0.749	3.50	2.43	0.012*
A10	Jidoka	4.00	3.20	0.172	3.00	3.00	1.00
A11	Heijunka	4.00	2.93	0.024*	2.67	1.80	0.169
A12	Standardization	4.00	3.80	0.484	4.25	3.43	0.034

* implies significant where P-value less than 0.05

Company A. For VSM and Kaizen, P-value of 0.05 indicates that they are close to being statistically significantly different between the perspective of Top Management and Executive. It is significantly different in how Top Management and Executive view the implementation of Cellular Manufacturing in Company B as shown in Table 5. Overall, the view of Top Management and Executive in Hard Lean Practice implementation is the same.

Table 6 Comparison of mean score and P-value for top management and executive in Section B for both companies

	Soft lean practices	Company A			Company B		
		Mean score (top management)	Mean score (executive)	P-value	Mean score (top management)	Mean score (executive)	P-value
B1	Employee awareness	4.67	4.16	0.004*	3.17	2.29	0.003*
B2	Quality of professional development	4.70	4.05	0.008*	2.38	3.00	0.122
B3	Production control	5.00	4.06	0.003*	2.75	3.26	0.088
B4	Supplier partnership	4.07	3.23	0.061	2.50	2.21	0.392
B5	Customer Involvement	4.80	3.95	0.016*	3.06	3.25	0.661
B6	Quality of leadership	5.00	3.85	0.000*	3.45	2.97	0.110
B7	Monitoring lean progress	5.00	4.27	0.002*	3.17	2.91	0.578

* implies significant where P-value less than 0.05

Meanwhile, In Section B, there is no significant difference between the view of Top Management and Executive regarding the Supplier Partnership as shown in Table 6. However, there are significant differences for the rest of the categories and this shows that there are differences in how Top Management and Executive see the condition in their company. From the table, the mean of Top Management is higher than Executive's in each category. Therefore, the Top Management of Company A might have overestimated the condition of lean implementation in their company.

From the result of Two Sample T-test in Table 6, there is significantly different for the Mean score of Top Management and Executive in Employee Awareness only. This reveals that Top Management might have overestimated the Employee Awareness in the company. For other six categories, there is no statistically significant difference between the view of Top Management and Executive. This might due to both Top Management and Executive have the same thought regarding the level of lean implementation in the company.

Based from the results of statistical analysis, Company A is having a better lean implementation compared to Company B. For Company A, the application of Hard Lean Practices was above average with a mean score of 3.62, while in Section B, the overall lean score for each category was relatively good, which is 4.14. The only weakness, Supplier Partnership only scored a value of 3.44. Therefore, Company A is suggested to focus on improving the score of Supplier Partnership. For Company

B, the application of Hard Lean Practices was at medium level and the lean score in Section B is only 2.85, which was below average. Therefore, Company B is in transition towards a better application of lean manufacturing. Company B is suggested to provide education and training to employees in order to understand the concept and purpose of lean. Knowledge and information sharing should be done with other similar plants, suppliers and customers in order to gain more knowledge and experience of how to implement lean successfully.

4 Conclusion

The objectives of this study are successfully achieved. A lean assessment tool in the form of Likert Scale Questionnaire was developed and validated by four industrial experts. The high values of Cronbach's Alpha show that the questionnaire is reliable. The questionnaire was used to measure the level of lean implementation in two electronics manufacturing firms. The level of implementation can be determined and compared by measure the mean score. From the results of T-Test, Company A is definitely having a better lean implementation compared to Company B. In summary, the developed questionnaire is able to explore the extent of lean manufacturing implementation in manufacturing firms. This tool has implication for the firms as it provides means score to determine the weakness and strength of a firm and compare the leanness of department within a firm. This tool also help to study employee perceptions at different positions.

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