A case study on Measurement of Degree of Performance of an Industry by using Lean Score Technique

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ABSTRACT: Lean manufacturing concept is becoming a very important strategy for both academicians and practitioners in the recent times, and Japanese are using this practice for more than a decade. In this present scenario, this paper describes an innovative approach for lean performance evaluation by using fuzzy membership functions before and after implementing lean manufacturing techniques and formulating a model to establish the lean score through the lean attributes by eliminating major losses. It shows a systematic lean performance measurement by producing a final integrated unit less-score.

Keywords: lean performance, lean metrics, lean score, fuzzy membership values, FMECA, TPM, Maintenance.

1. Introduction

Lean manufacturing tools and techniques are well knowingly popularized over the last two decades and bringing a remarkable change in all the wings of the manufacturing systems. In this contrast, particularly managers are going ahead in productivity by eliminating wastes through lean manufacturing tools and techniques. In this contrast, cost, quality and just in time (JIT) delivery and continuous improvement are playing a vital role [1]. Now-a-days, more companies are going to implement lean manufacturing tools and techniques, to become alive in this competitive global market and collectively striving to give the best to the customers A number of models and techniques were developed and discussed for the measurement of lean and its practices [4, 7]. Previously qualitative techniques such as surveys are used to measure lean performance level [7, 10]. But the results obtained by the surveys vary from different individuals [8]. The past few years have witnessed a tremendous growth in the number and variety of applications of fuzzy logic (FL). With the help of fuzzy logic, we can specify mapping rules in terms of words rather than numbers. Calculating with the words gives us imprecision and tolerance. The basic fundamental of fuzzy logic system was given by Bojadziev and Bojadziev [6]. Malay niraj [9] has given the heuristic approach for the frequency of maintenance and type of maintenance required for a firm on the basis of criticality and severity of the factors responsible. In this paper he has differentiated the best practices of TPM, basing on the criticality.
1.2 Problem overview

In order to resist the competition of the global market conditions, every manufacturing company is trying to adopt the best techniques and methods to get the best output. So in this scenario, everyone are concentrating more on the elimination of waste, rather than implementing techniques. As the implementation of new techniques, machinery, training to employee’s results in more expensive. This paper emphasizes mainly on the elimination of major losses with the help of lean score.

2. Methodology

2.1. Measurement of lean score

For the measurement of lean score firstly we have to get data from the manufacturing unit and we have to get a deep study about the firm. In this study, Elimination of wastes, Continuous improvement, Zero defects and JIT deliveries are identified as a most important lean performance attributes which draws more attention for studying of the firm. Each lean attribute is measured with respect to cost, quality and time based categories for the performance of waste elimination and deliveries has been taken for measurement of JIT. Continuous improvement has to be given to all levels of the categories which is shown in figure 1.

![Figure 1. Classification of lean metrics](image)

While measuring the performance of the each attribute, it is difficult to choose the number of metrics for the best results. In this context the author have taken two metrics for some attributes and three for some attributes and are tabulated below in table 1 and the metrics are numbered. As the number of metrics increases, the lean score obtained is that much sensitive.

| Lean Attribute       | Performance Category | Metrics (M) | Description                      |
|----------------------|----------------------|-------------|---------------------------------|
| WASTE ELIMINATION    | Quality Loss         | 1           | Product Loss                    |
|                      |                     | 2           | Number of customer complaints    |
|                      | Availability Loss   | 3           | Breakdowns                      |
|                      | JIT                 | 4           | Set up and Adjustment Loss      |
Now the author wants to bring the relation between each metric. So now he tries to calculate the performance of each metric and finally to get the unique lean score. Here the author implemented some formulae’s for calculation which are tabulated below in table 2.

Table 2. Performance metrics and their indexes.

| Metric                          | Formula                                                                 |
|---------------------------------|------------------------------------------------------------------------|
| Product Loss                    | $M = \left( \frac{\text{Number of start up rejects} + \text{Number of production rejects}}{\text{Total number of products}} \right) \times 100$ |
| Number of customer complaints   | $M_2 = \left( \frac{\text{Number of customer complaints}}{\text{Total number of complaints}} \right) \times 100$ |
| Breakdowns                      | $M_3 = \left( \frac{\text{Break down time}}{\text{Planned production time}} \right) \times 100$ |
| Set up and Adjustment Loss      | $M_4 = \left( \frac{\text{Time taken for setup and adjustment loss}}{\text{Planned production time}} \right) \times 100$ |
| Shutdowns                       | $M_5 = \left( \frac{\text{Number of shutdowns}}{\text{Total planned shutdowns}} \right) \times 100$ |
| Speed Loss                      | $M_6 = \left( \frac{\text{Actual production}}{\text{Desired production}} \right) \times 100$ |
| Stoppage Loss                   | $M_7 = \left( \frac{\text{Minor stoppage time}}{\text{Operating time}} \right) \times 100$ |
| Non Value Added Time            | $M_8 = \left( \frac{\text{Idle time} + \text{Interference time} + \text{Line balancing loss}}{\text{Operating time}} \right) \times 100$ |
| Annual Inventory Costs          | $M_9 = \left( \frac{\text{Annual inventory cost}}{\text{Total annual sales}} \right) \times 100$ |
| Annual Transportation Costs     | $M_{10} = \left( \frac{\text{Annual transportation cost}}{\text{Total annual sales}} \right) \times 100$ |
| Orders Delivered Late           | $M_{11} = \left( \frac{\text{Orders delivered late}}{\text{Total deliveries}} \right) \times 100$ |
| Dispatch Time                   | $M_{12} = \frac{\text{Average total number of days from orders received to delivery}}{\text{Total deliveries}} \times 100$ |

Now we have to set the fuzzy area and membership functions for each performance metric by taking two values as point A and point B. Point A represent the best performance and point B
represents the worst performance of the given metric. So by using those, we can fuzzify the metrics and can bring the fuzzy membership values to each metric, where the continuous improvement is given to all the metrics. Graphically, triangular areas are obtained to show the fuzzy areas and the membership values for the each metric can be obtained from Bojadziev and Bojadziev [6].

\[
\mu_{F(M_i)} = \begin{cases} 
1 & \text{if } M_i \leq a \\
\frac{1}{(b-a)} (M_i - a) & \text{if } a < M_i < b \\
0 & \text{if } M_i \geq b
\end{cases}
\]  
Eq. (3)

From the fuzzy set areas the author says that the point A is fixed its all values to zero, as it indicates the best performance of all metrics and the values at A must be reduced as much as low he can. At point B the worst performance has to be noted at that period. Fixing the points A and B is arbitrary and can be changed to different values by the manufacturer’s analyst.

Now, it is time to calculate the lean score by taking average of all the performance metrics membership values. This score will be used as for lean evaluation the firm and used for the better improvement in the particular areas of the manufacturing unit.

Lean performance score can be calculated from Farzad Behrouzi and kuan Yew Wong [5]

\[
\text{LEAN SCORE} = \left(\sum_{i=1}^{12} \frac{\mu_{F(M_i)}}{12}\right) \times 100
\]  
Eq. (4)

2.2. Classification of lean attributes

From the above relation, we can measure the performance of an individual firm. In the same way, the author had a survey around 30 industries in India, and obtained different lean scores for various industries. Basing on the lean score data of a particular industries, the author tries to differentiate the lean score s into different zones and they are tabulated below in table 3.

| Lean Score | Severity |
|------------|----------|
| 0<=25      | Super critical |
| 25>=40     | Critical    |
| 40>=60     | Less critical |
| 60>=100    | Safe performance |

| Table 3. Severity zones based on lean score |

Basing on the data of the industrial survey, the author categorized the lean performance metrics under the lean severity zones which are tabulated in Table 4.

| Table 4. Classification of lean metrics based on severity. |
|-----------------|-------------------|-----------------|-----------------|-----------------|
| Super Critical  | Critical          | Less Critical   | Safe Performance|
| Breakdowns      | Critical          | Non value added time | Annual inventory loss|
| Setup and adjustment loss | Speed loss      | Late delivery     | Dispatch time   |
| Stoppage loss   | Product loss      | Customer complaints | Annual transportation cost |
Basing on the severity of the lean metrics, the author suggests the required maintenance practice and frequency of maintenance required from Malay Niraj [9].

| Severity            | Maintenance Practice          | Frequency of Maintenance         |
|---------------------|-------------------------------|----------------------------------|
| Super Critical      | TBM & CBM both                | Daily or Twice a day             |
| Critical            | CBM                           | Daily or Twice a Week            |
| Less Critical       | CBM or Breakdown Maintenance  | Monthly or fortnightly           |
| Safe Performance    | Breakdown Maintenance         | At the time of failure           |

3. Illustrated example

For the sake of better understanding of the proposed measurement model, an example is presented here. Let us consider a manufacturing unit and its data has been collected and its performance metrics has been calculated and tabulated as per our proposed measurement model below. Obviously from the data the final lean score (30 out of 100) which obtained was not that much satisfactory. Further it needs a lot of improvement in its lean performance metrics. From the table it is seen that the performance metrics $M_2$, $M_{11}$ are out of the fuzzy areas and their respective membership values are equals to zero. This means, there is a lot of chance for the better improvements. Similarly metrics $M_1$, $M_3$, $M_4$, $M_6$, and $M_7$ are categorized as major six big losses of the manufacturing systems. A little change in these performance results in a huge variation of the lean score. These metrics need more concentration and better improvements. In the same way, metrics $M_8$, $M_9$, $M_{10}$, and $M_{12}$ are having very poor performance and needs more improvement in their processes. In this study the weights of all performance metrics is same but individually different by depending on their importance. The author suggests that for future work contains some more metrics and can get more sensitive lean performance score.

| Metric | Hypothetical Performance Data | Point A | Point B | Membership value |
|--------|-------------------------------|---------|---------|------------------|
| $M_1$  | 2.41%                         | 0       | 4%      | 0.39             |
| $M_2$  | 5%                            | 0       | 4%      | 0                |
| $M_3$  | 4.1%                          | 0       | 6%      | 0.31             |
| $M_4$  | 6.09%                         | 0       | 8%      | 0.23             |
| $M_5$  | 1%                            | 0       | 2%      | 0.5              |
| $M_6$  | 0.87%                         | 0       | 2%      | 0.56             |
| $M_7$  | 4.13%                         | 0       | 7%      | 0.41             |
| $M_8$  | 9%                            | 0       | 14%     | 0.35             |
| $M_9$  | 7%                            | 0       | 10%     | 0.3              |
| $M_{10}$| 3%                            | 0       | 5%      | 0.4              |
| $M_{11}$ | 6%                          | 0       | 2%      | 0                |
| $M_{12}$ | 12%                         | 0       | 14%     | 0.14             |

LEAN SCORE 30
3.1. Graphical data of lean performance values.

Here as the author already discussed about the triangular fuzzy membership values for the lean performance values of the firm. In this context, he had given the graphical representation of the lean performance value of the individual lean metrics before implementation of the TPM best practices. He had made this pictorial view with the initial data shown in the graph 1.
Graph.1  Graphical representation of fuzzy membership values for lean attributes.

4. Results

In this paper, initially the author concentrates on the two important variables of leanness and next he extracts the corresponding metrics and finally brings a relation between them by using fuzzy membership functions in order to find out the unique lean score of the manufacturing unit. The same process is adopted among 30 industries in Jamshedpur and got their individual lean scores. Basing on the data, he categorized the lean score into different severity zones. Basing on the severity, he differentiated the lean metrics and best practices of TPM. Following his study, he adopted the best practices of TPM and frequency of maintenance at an appropriate period of time, and he once again
calculated the lean score which gives a tremendous increment in his results which are tabulated below in Table 7.

| Metric | Hypothetical Performance Data | Point A | Point B | Membership value |
|--------|-------------------------------|---------|---------|------------------|
| M₁     | 1.8%                          | 0       | 4%      | 0.55             |
| M₂     | 3%                            | 0       | 4%      | 0                |
| M₃     | 3.02%                         | 0       | 6%      | 0.49             |
| M₄     | 4.03%                         | 0       | 8%      | 0.50             |
| M₅     | 1%                            | 0       | 2%      | 0.5              |
| M₆     | 0.62%                         | 0       | 2%      | 0.69             |
| M₇     | 3.01%                         | 0       | 7%      | 0.57             |
| M₈     | 6.4%                          | 0       | 14%     | 0.54             |
| M₉     | 5.7%                          | 0       | 10%     | 0.43             |
| M₁₀    | 2%                            | 0       | 5%      | 0.6              |
| M₁₁    | 4.7%                          | 0       | 2%      | 0                |
| M₁₂    | 7.3%                          | 0       | 14%     | 0.47             |

**LEAN SCORE** 44.5

From the table it is observed that the quality has a very little improvement, as it is very nearer to the 100% percent and coming to the availability there is an around 3% improvement in a short time. Coming to the performance of the machines, there is an improvement of around 4% and in cost 2% and a huge improvement in the delivery up to 6%. So by seeing the above, it resolves clearly that there is a marginal increment in the lean score after implementation of the TPM best practices and adopting suitable remedies. Now he graphically showed the results of various lean metrics before and after implementation of his study in figure 2.

![Figure 2. Comparison of lean performance metrics](image)

**5. Conclusion**

By using the fuzzy membership values, this study has given the steps to a performance measurement method to measure the lean performance of the manufacturing systems. Waste elimination and JIT
deliveries are considered as the most important lean attributes for the improvement of the industry. Cost, quality and time are regarded as surrogates for the waste elimination and delivery is taken as surrogate for JIT deliveries and corresponding metrics have been taken for each surrogate and finally calculated the lean score before and after implementation of TPM best practices at a particular instant of time, which will be used for the managers and the high level superiors to work more to get more efficient plant. The results were compared and shown graphically. The most salient parameters like product loss, customer complaints and dispatch time loss has improved by 0.61%, 2% and 4.7% at a short period of time. In order to achieve a more sensitive and accurate lean score, more attributes have to be considered.

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