Lean Implementation on Production Process and Maintenance Practice for Productivity Improvement

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Abstract: Lean concept has been discussed extensively across many industries. As its approach to ensure overall performance by a focus on delivering customer's expected value. Any activities within industries that don't contribute to value the end product will consider as waste and need to be eliminated. The lean idea for the Bogie production process useful to identify the potential improvement in production performance in terms of manufacturing lead time (MLT) or cycle time. Carefully analyze the cause of waste may guide to address the root cause. One of them is a maintenance problem. Therefore, the continuing lean implementation of maintenance activities may lead to solving another root cause. It successfully showed the potential escalation on MLT, about 20% reduced by considering the manufacturing waste. Further advantage and benefit may gain more due to lean maintenance implementation, albeit the exact improve performance still need to be detailed quantified.

1 INTRODUCTION

Lean concepts firstly proposed by Taichi Ohno in the late 1940s. Toyota Production System showed significant achievement in several areas, including productivity and efficiency, as well as production cycle time. The lean implementation relies on five basic principles. Firstly, value identification defined by the customers' expectations about the end product. Second, mapping the process workflow within the company involved in delivering the end product. It will identify in what process the value has been generated, include the proportion of processes that do not cause to value. Third, disperse work into smaller batches and visualizing the workflow, to ensure continuous workflow and easily identify the possible bottleneck and interruption. Fourth, establish a pull system means optimizing the production capacity and delivering a product based on actual demand, ensuring no waste on resources. The last, encourage all components of the company actively involved in creating the continuous improvement program.

Bogie production consists of many processes. The current situation detected in the shop floor was lack of documentation both in production/machine capability, workforce capacity, and many outcome measurements include cycle time and production rate, which is very important for providing the baseline performance and detecting any obstacles. This condition may cause any difficulty in addressing the improvement program on production capability. Bogie product of the company being studied is a chassis or framework that carries a wheelset, and this is a modular subassembly of wheels and axis that attached to a train. At least two bogies need to be assembled beneath the train. Moreover, the company instructs to increase the capability of producing the bogie to reduce the tardiness of product completion and shipment, as well as to reduce the number of rework products. Another issue identified in the company related to maintenance activities that responsible for restoring any machine failure back into operation state. It triggered by the high frequency of machine failure that causes corrective maintenance instead of a preventive one. Downtime may effect reducing availability and high inventory work in the process. In the end, the same problems reveal in reducing the number of Bogie production.

Therefore, this paper attempts to capture the current production process to identify potential improvement by reducing or eliminating the seven waste on Bogie production. The lean approach has been chosen to be implemented both in the production process and maintenance activities, as the benefit of the promise of lean implementation has reported

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(Rohani and Zahraee, 2015; Madaniyah and Singgih, 2017). The combined lean implementation both on production and maintenance at the same shop floor to be expected can double the benefit and advantage of lean. Some tools employed include Value Stream Mapping (VSM), Operation Process Chart (OPC), and Cause Analysis (CA).

2 RESEARCH METHODOLOGY

The lean implementation on the production process called lean manufacturing, while implemented on maintenance practice, becomes lean maintenance. The steps taken were accommodating the five basic principles of lean. Initially, the production process needs to be clearly identified using Operation Process Chart (OPC).

Value Stream Mapping (VSM) used to visualize the information and material flow within a process, followed by identifying the appropriate waste i.e., seven waste for lean manufacturing, eight waste for lean maintenance. The third step is flowed the value by mapping all the activities into three categories: value-added activity (VA), non-value added an activity (NVA), and necessary but non-value added activity (NNVA).

The pull system brings to evaluate several performance measurements i.e., manufacturing lead time (MLT) for production and overall equipment effectiveness (OEE) for maintenance. The final step is continuous improvement by eliminating the waste by audit, standardization, and identify the cause of waste.

3 LEAN FOR BOGIE PRODUCTION

There are 25 process routing in order to produce one unit of bogie (called bogie set), that consists of two bolsters and four side frame.

3.1 OPC and VSM of Bogie Production

The routing processes and its cycle time is provided in Table 1.

Table 1: Process routing and its cycle time.

Process	Cycle time (mins of producing 30 product)
Core making	420
Mold making	240
Core setting	210
Melting	525
Pouring	80
Shake out	210
Cutting	300
Swing grinding	675
Hand grinding	600
MPI 1	150
Welding repair 1	640
Heat treatment (normalizing)	505
Shot blast	285
Machining	320
Finishing & gage inspection	500
MPI 2	150
Welding repair 2	245
Final inspection (internal)	30
Assembly	180
Final inspection (external)	240
Packaging	210

All the processes above done serially except the first three processes conducted in parallel at the same time. By categorize the activities during VSM into O (operation), T (transportation), S (storage), dan D (delay), the distribution of their VA, NVA, NNVA frequencies are provided in Table 2.

Table 2: Process activity mapping.

Activity	VA	NVA	NNVA	Time (mins)	Percentage
O	47	9	2	10265	60%
T	0	0	17	630	4%
I	0	0	9	220	1%
S	0	1	0	60	0%
D	15	0	0	5820	34%

The calculated MLT for bogie production is total cycle time + transportation time = 675 mins + 20 mins = 695 mins, or 208 hours, or 8,6 days.

3.2 Waste Identification in Bogie Production

There is critical waste includes waiting and inventory. The waiting data is given in Table 3 as follow:

Table 3: Process activity mapping.

Waiting	Time (mins)
Waiting in mold making queue	180
Mold making wait core making	180

Melting wait core setting	315
Waiting for pouring until packaging	645
Total waiting	1320

Total waiting is 22 hours or 0.9167 days. Another critical waste is transportation, consume 695 mins or 11,58 hours. While excess processing, transportation, and motion also being identified. The defect product was recognized into two types i.e., gas hole, crack, shrinkage, and cold shut, as provided in Table 4.

Table 4: Waste defect.

Defect type	Repair	Probability repair	Repair time (mins)
Gas hole, cracks, shrinkage	Welding repair 1	67%	640
Mold making wait core making	Welding repair 2	33%	245
	tempering	3%	127.05
Shrinkage could shut	Re-melting	0,23%	31.275

The total repair time would be 646.721 mins or 17.38 hours.

3.3 Root Cause Analysis (RCA) for Bogie Production

The following steps after waste identification are finding the cause of waste by applying the RCA diagram. For defect waiting, the appropriate RCA is given in Figure 1. The root of the problem shows by the circle symbol. From Figure 1, it can recognize that one of the root cause for waiting is machine breakdown. The historical data shows the proportion of corrective maintenance is almost 80%, which means the maintenance activities don't well planned. This situation triggered to analyze the current maintenance activities by using a lean maintenance approach, which slightly different from the lean manufacturing approach both on the waste category and the value characteristics.

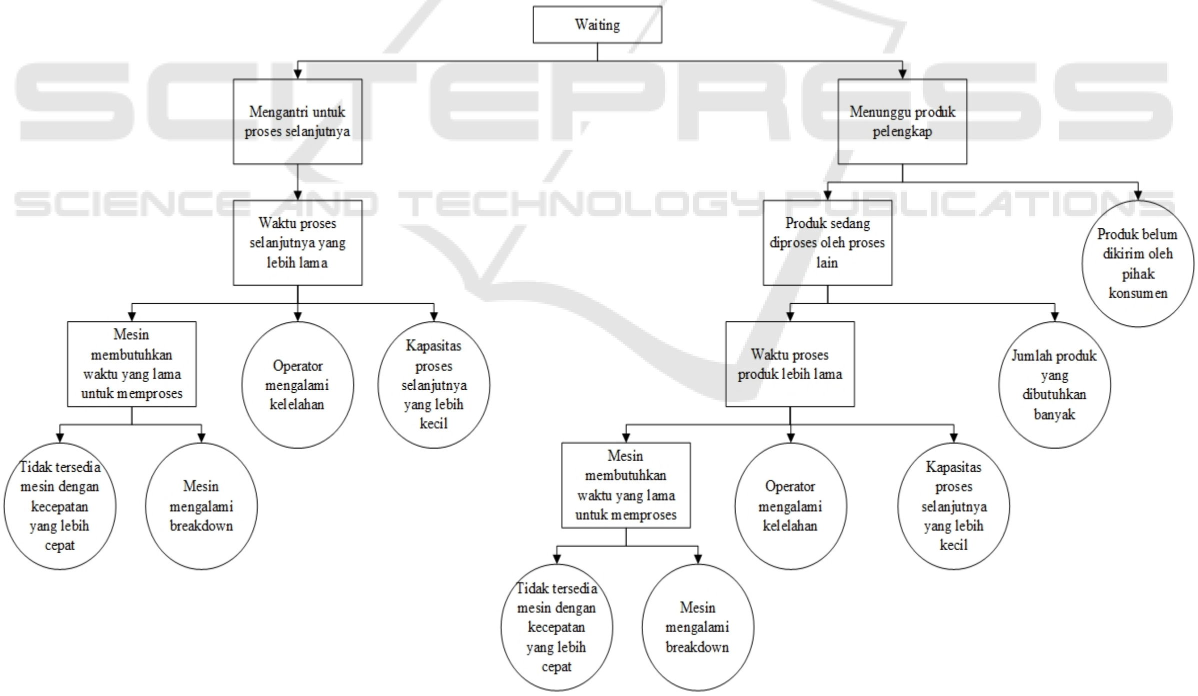

Figure 1: Root cause analysis of waste waiting

4 LEAN MAINTENANCE FOR BOGIE PRODUCTION MACHINE

Machine failure characterized by downtime is provided in Figure 2. Under the standard downtime of 5%, there are three critical machines that need to address.

Implementation of lean maintenance follows the framework proposed by Mostafa et al. (2015), as depicted in Figure 3.

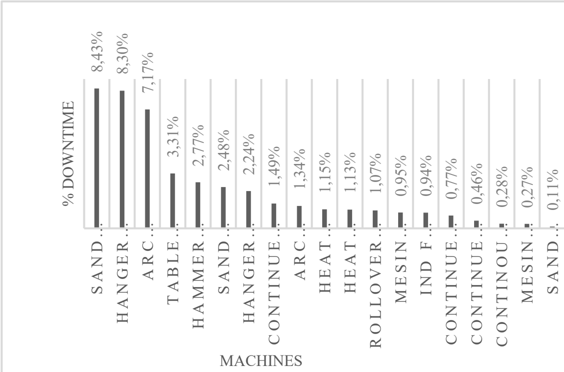

Figure 2: Downtime of machine production

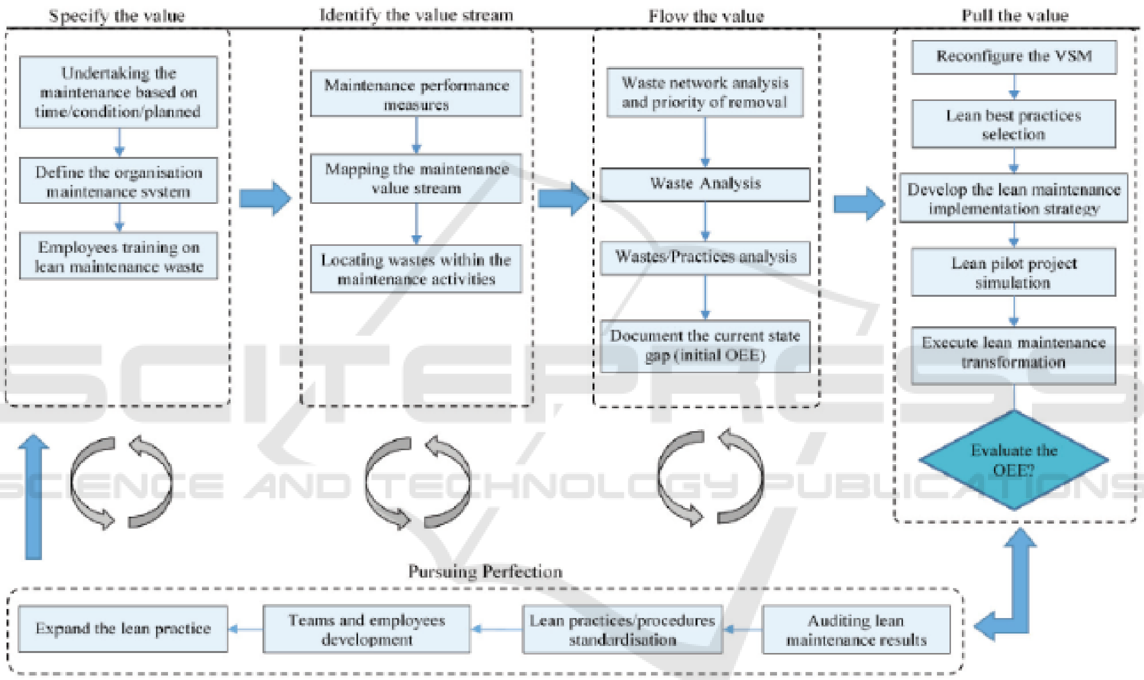

Figure 3: Lean maintenance framework

4.1 Specify the Value, Value Stream, and Flow of Value in Maintenance

Based on the waste of maintenance as proposed by Davies and Greenough (2002), waste of maintenance can be categorized into eight types as follows: unproductive maintenance, waiting for maintenance resources, centralized maintenance, poor inventory management, unnecessary motion, poor maintenance, ineffective data management, and under-utilized of resources.

Based on the value stream maintenance mapping (VSMM), among 51 activity of maintenance can be grouped into 26 VA, 21 NNVA, and 3 NVA.

4.2 Pulling the Value of Maintenance

The performance of maintenance can be identified by OEE measures. OEE determined by availability, performance, and quality. The world-class maintenance should have 85% OEE.

Availability rate calculated from uptime divided by total loading time. The uptime is total loading time subtract by downtime. Historical loading time, planned unplanned downtime bring the value of availability rate in 96.7%.

Performance measures how good the machine produces the product determined by total actual cycle time divided by total operation time. The historical data shows only 41.3% (under the standard minimum of 60%).

The quality rate measures the proportion of good product among all product produced by manufacturing. Historical data shows a 100% quality rate. This means all rework due to imperfect pouring and casting was successfully resolved by the machining process conducted after the cooling process done.

Based on the value of the OEE component, the demonstrated OEE is around 40.2% with containing slightly increasing trend during 1,5 years of data. The summary of losses is provided in Table 5 as follows.

Table 5: Six Big Losses.

Losses type	Time (hours)
Equipment Failure	222.75
Setup and Adjustment	0.00
Idling and Stoppages Minor	1198.58
Reduced Speed Losses	537.31
Process Defect	0.00
Reduced yield (start-up)	0.00

Based on Table 4, it can easily be recognized that the largest portion of losses is idling-stoppage and speed losses.

4.3 Continuous Improvement of Maintenance

Instead, all the quantitative performance measures of lean maintenance that already calculated, carefully figure it out the existing condition shows some issue as follows:

a. Availability of maintenance operator. Responsibility to handle all the maintenance tasks for all production facilities may expose over the worked condition, especially when several machines fail that need to be maintained at the same time. Therefore, as the concepts of TPM suggest that the machine operator could be trained as the maintenance crew since they can identify easily and rapidly whenever the failure mechanism happened on the machine where they operate.
b. Job safety analysis has been produced for several parts of the machine and production area. The health issue for the operator is also important to concern.
c. The administration of maintenance activities and data need to be carefully stored by the system — technical maintenance library as a database of maintenance useful for any decision taken for maintenance.
d. Part warehouse needs to be managed in order to easily quantify the available spare as well as the spare part demand. Rearrange of the spare part placement on the rack will help the operator to find the spares need and minimize the searching time.
e. Fault tree analysis (FTA) for each maintenance waste will help the company to identify the correct response to the problem reveals as well as to prevent the same problem happened in the future. The FTA for poor maintenance and reduce speed loos was developed, as provided in Figure 4.

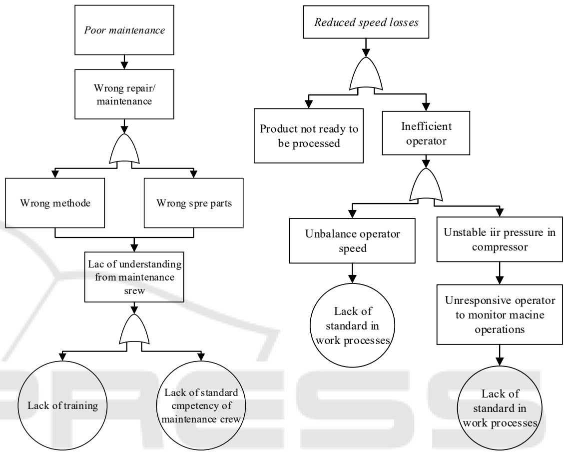

Figure 4: FTA of maintenance waste and looses

4.4 Designing the Overall Measure of Maintenance Performance based on the Lean Concept

By considering many factors in maintenance performance suggested by Smith (2003), the proposed key performance indicator for the maintenance department as follows:

a. Monitor the OEE, by providing measurement on MTBF, MTTR, MTBF of each machine trough reliable failure data collection mechanism
b. Monitor the percentage of the PM work order.
c. Develop an effective planning and scheduling maintenance
d. Monitor store service level (% stock out)
e. Design and evaluate the proper training to improve the skill of maintenance crew as well as the standardization of maintenance task by providing SOP for maintenance
f. Measure the overtime proportion of maintenance crew for completing the job

g. Calculate the maintenance cost relatively compare to the production rate.

5 CONCLUSIONS

Lean manufacturing successfully implemented to manage the improvement of the Bogie production process. The OPC highly contributes to shows several processes that consume the largest production time. Moreover, re-evaluate of NVA may drive to identify the potential reducing time to escalate the MLT. From the simulation of the production process, the potential improved MLT is 6.9 days from the previous 8.63 days.

By carefully find the cause of manufacturing waste, it brings to another problem of maintenance activities. Therefore, deep analysis of lean for maintenance activities brings the proposed idea of improvement on standardizing the process of maintenance, managing spare part inventory, and identifying scheduled maintenance as well as developing skill improvement programs for the maintenance crew. All the suggested proposed programs ensure the leanness of maintenance activities that further will put more value for leanness in the production process.

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