Analysis of Changing Working Patterns on an Overhaul Activity in a Power Plant Industry using Lean Manufacturing Concept

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Abstract. East Region Maintenance Service Unit (UPHT) has three main targets to implement maintenance activities, namely on quality, on cost, and on time. These three targets are a form of UPHT commitment in maintaining customer confidence on work result. PT PJB (Bali Java Generation) wants UPHT to optimize the duration of overhaul time. The possible strategy could be applied consists of detailing working breakdown structure (WBS), working in two shifts, roll in - roll out spare parts, and the establishment of a competent quality control team. In this research, value added, non-value added, necessary non-value added, and workload activities were analyzed to optimize quality, duration, profit and minimize budget on project management overhaul gas turbine units. The instrument used in this study were Yamazumi Chart and NASA-Task Load Index (NASA-TLX). The results showed the percentage of value added activity was 38%, necessary non-value added was 51% and non-value added was 11% of the total overhaul. There is the potential to shorten the duration of the major overhaul changes in work schedules from those originally scheduled for 32 days, to only 18 days by using the two-shift pattern. The profit earned from shortening the duration of the overhaul is IDR 2,500,975,763.74.

1. Introduction

The East Region Maintenance Service Unit (UPHT) is one of the power plant maintenance units owned by the Bali Java Generation (PJB) with specialization in work on planned inspections (overhauls). In accordance with the Directors Decree (SK) No. 040.K / 010 / DIR / 2007 dated April 3, 2007, UPHT serves maintenance of generating units owned by PJB in the eastern part of Java island, including PLTU / G / GU Gresik, PLTU Paiton Unit 1 and 2, and PLTA Brantas which spread in East Java. In carrying out maintenance activities, UPHT has three main targets, namely on quality, cost, and time. The three targets are a form of UPHT’s commitment in maintaining customer trust in the results of their work.

In the middle of 2017, two companies engaged in the energy sector namely SIEMENS and MAPNA submitted an offer proposal to overhaul the gas turbine unit with a duration of 15-17 days in the scope of the major inspection (MI) work. The standard time duration on scope MI of the Mitsubishi Heavy Industry (MHI) gas turbine manufacturing plant is 45 days. However, along the way by implementing the strategy - acceleration strategy, UPHT succeeded in accelerating the duration of the gas turbine overhaul to 32 days. With the proposals submitted by the two companies, PJB directors see profit opportunities if the overhaul can be accelerated to 15-17 days.

Starting from the proposal and challenge, PJB wants the UPHT to optimize the duration of the overhaul time. The strategy studied was to detail the work breakdown structure (WBS), work in 2 shifts,
roll in - roll out spare parts, and establish a competent quality control team. With the limitations, the strategy is implemented in the gas stem power plant PLTGU GRESIK GT 1.3 overhaul in July 2018. As a result of the implementation of the strategy, UPHT can accelerate the duration of work to 24 days. However, there are some drawbacks and weaknesses of implementing the strategy, namely a high workload of workers, a small amount of quality human resources, the expected profit is not in line with expectations. The problems that occur are caused by weak project management planning. Determining the quantity of HR and material is the initial parameter to determine the duration and budget of a project management. In addition, the readiness of less competent human resources is the next problem. Though the competence of an HR is an important factor in monitoring the process and results in a job. One method that can be used to evaluate the operational activities of a company is lean manufacturing. The method provides a strategy to increase efficiency in the production line by eliminating activities that cause waste. According to [1], types of operation could be classified as three categories, i.e. value adding, non-value adding and necessary but non-value adding activity. Valuable activity refers to activities that can increase value in the production process. While activities that are not valuable focus on activities that can waste time, salary, material uselessly. Necessary but non-value adding activity involves wasteful action but is necessary to be done under accustomed operating procedures, for example picking up parts located in several meters, and removing a tool from one site to another. Lean manufacturing methods have been applied to solve waste problems in the production process. [2] conducted a lean manufacturing approach to the furniture production process at PT Gatra Mapan to overcome the mismatch of production output with the production target. The results of the study show that the most common waste is defect and waiting time. By making repairs, the cost of value-added activities / production costs of one product (Dino Sideboard 2 D 3 DRW SN - WG) was reduced by IDR 24,000. [3] used the concept of lean manufacturing to increase productivity in packaging bag companies. After the repairs were carried out, there was a decrease in production time from 138.4 minutes to 119.4 minutes. Therefore, in this study, it is necessary to map resource activities in the form of value added, non-value added and necessary added to find out how effective work time for completing work and also workload should be analyzed to find out how much mental burden is experienced by workers. The results of workload analysis can be used as input in the implementation of subsequent overhauls to optimize the duration, profit and minimize the budget for the management of the project to overhaul the gas turbine unit. The novelty of this work is related to the object used in the study. Various literatures have not shown the implementation of lean manufacturing concept in a power plant industry, especially in the case of analyzing overhaul activity. One of the instruments used to measure worker workload is NASA Task Load Index. [4] conducted a study of measuring ICU nurse workload. The results of the study show that NASA-Task Load Index is the most reliable instrument compared to other instruments. [5] used NASA-TLX to evaluate the workload of railroad industry workers in Australia and found that workload significantly affected fatigue. [6] used NASA-TLX to assess the mental workload of individual.

2. Methodology

2.1. Identification of problems
The problem identification process was carried out at PT PJB Unit Gresik in the gas-steam turbine section. Most problems commonly occur due to the absence of a suitable number of workers during the overhaul process. If the number of workers is excessive, then some workers are too relaxed at work. However, lacking of workers cause a higher workload of each person.

2.2. Data collection
Primary data was taken by conducting interviews with workers who took a part in overhaul work. While secondary data consists of existing project management designs, Work Breakdown Structure (WBS)
and Organizational Breakdown Structure (OBS) during overhauls, overhaul project budget data, and overhaul quality criteria, i.e. performance and Equivalent Force Outage Rate (EFOR).

2.3. Data processing

This stage begins by processing data value added activity (VA), necessary non-value added activity (NNVA), and non-value added activity (NVA) data using the Yamazumi chart. Then, mental burden is measured based on the results of the NASA TLX questionnaire. The proportion of VA, NNVA and NVA activity, which is the output of Yamazumi chart results, compared to the results of NASA TLX. Furthermore, the standard time and number of ideal operators will also be calculated.

3. Data analysis and discussion

3.1. Work Sampling Analysis

Based on the work sampling observation data conducted on the overhaul of the gas steam turbine major inspection, there were 85 measured activities that affected the turbine inspection overhaul project. The majority of data are activities that are physical activities, where the percentage of value added activities is 38%, necessary non value added is 51% and non-value added is 11% of the overall overhaul duration.

Of the three activities, necessary non value added activities have the highest value, necessary non value added activities have a portion of 51%, which in this percentage consists of 59% flushing oil, 16% bolt heating, 7% hauling activity, tool preparation and personal protective equipment, 4% alignment preparation, trip from the tool box to each work position 3% and other activities 4%.

In necessary non-value added activities, the first ranking that dominates is the activity of flushing oil, where flushing oil is an activity of filtering lube oil to remove contaminants on lube oil until it reaches the criteria specified by the manufacturer. To speed up this process, making tools external flushing has been carried out, so that the process can be carried out independently without waiting for all line lube oil to be closed and the use of heavy-duty magnets placed on the oil filter to trap contaminants in the form of ferrous magnetic material. However, apparently these methods have not been significant to reduce the duration of flushing oil activity.

In the second necessary non-value added activity that dominates is the activity of heating bolts, where in the case of disassembly or reassembly of the casing bolts must be preheated so that elongation occurs. Currently to heat the casing bolts still use conventional bolt heaters. This technology will be eliminated in the future by using a bolt induction heater, which can cut the time 3-4 times faster than using a conventional bolt heater.

The third necessary non-value added activity is transportation equipment activities, where transportation equipment activities are activities of mobilizing components that have been disassembled or reassembled to be placed in a predetermined layout. The condition of transport activities at this time has been optimally carried out, because during overhaul use 2 to 3 overhead cranes simultaneously.

In the fifth necessary non value added activity is the activity during the alignment process between the turbine gas rotor and the generator rotor. At this time, a rotor alignment process still applies conventional methods with dial indicator equipment. But with the development of technology, there is a new method, namely laser alignment that has a better accuracy than using an indicator dial. If the plan for using a laser alignment is applied during an overhaul of major inspection, it will reduce the settling time 2-3 times faster. But in necessary non-value added, tool preparation activities, coordination between workers and others are in optimal condition.

While the value of non-value added activities includes the delay of workers in fulfilling a predetermined work schedule, lack of discipline and weak supervision make it easy for workers to violate agreement on work schedules, where the average delay for work ranges from 15-20 minutes from the specified schedule. Physical activity that drains workers also contributes to resting or returning sooner, which ranges from 5–15 minutes from the specified schedule. Activities such as drinking, taking a short break or personal needs such as going to the restroom can be suppressed.
### 3.2. Mental Workload Analysis

#### 3.2.1. Outsourcing Worker Mental Workload. In the analysis of workload, determining the criteria for workload refers to the results of the research [7], which updates the types of workload criteria based on the types of work. From the observation of workload data using the NASA-TLX method, a total of 170 questionnaires were given to workers who were in activities on a critical path, and the results of processing mental load data the NASA-TLX score average was 75.57, which according to [7], the value is included in the "Maximum" criteria.

#### Table 1. Value of outsourcing worker indicators

| No | Category                  | Average (Rating x Weight) |
|----|---------------------------|----------------------------|
| 1  | Mental Demand (MD)        | 152.00                     |
| 2  | Physical Demand (PD)      | 221.00                     |
| 3  | Temporal Demand (TD)      | 241.00                     |
| 4  | Performance (OP)          | 223.00                     |
| 5  | Frustration Level (FR)    | 52.20                      |
| 6  | Effort (EF)               | 243.99                     |
|    | WWL                       | 1133.59                    |
|    | Average WWL               | 75.57                      |

Based on Table 1, the indicator that has the highest value is effort (EF) and the indicator with the lowest value is frustration level. The effort indicator shows how much effort is spent mentally and physically needed to achieve worker performance. In an interview, workers stated that they felt they had spent effort physically and mentally in doing work every day. While the lowest indicator, frustration level describes feelings of insecurity, despair, irritability, stress during the work. This is because in overhaul work there are operational standards of work (SOP) that have been well designed, such as work instructions, use of personal protective equipment (PPE), breaks. In addition, for jobs with heavy physical drainage, such as disassembly of the turbine casing and compressor casing, the coordinator provides time allowance, so workers do not feel depressed.

Meanwhile, indicators of temporal demand, performance, physical demand, and mental demand are in the order of 2, 3, 4, and 5 respectively. The temporal demand indicator shows how much time pressure is felt by workers in completing work tasks. The observations show that in every major inspection overhaul there are always ideas that arise from the operations director, General Manager (GM) and production manager to reduce the duration of the overhaul, so that workers feel depressed in terms of time allocation.

Performance categories indicate the level of success and satisfaction in completing work. The average job with a high level of performance is assembly. This is because assembly work requires a lot of effort, so when the work is finished, the outsourcing worker feels relieved and satisfied. While work with a lower level of performance is lifting. This happens because lifting work does not have significant complexity.

The Physical Demand (PD) indicator shows the need for physical activity at work. All work carried out by outsourcing workers always involves physical activities, such as removing turbine casing insulation, disassembling turbine manholes, etc. Mental Demand (MD) is the second lowest indicator that shows the demands of mental and perceptual activities needed in work, such as thinking, deciding, counting, remembering, seeing and looking. This is because the type of overhaul major inspection work carried out by outsourcing workers is mechanical and only relies on physical activity. While work with mental activity during an overhaul is carried out by employees of PT PJB UPHT.

#### 3.2.2. PT PJB UPHT Employee Mental Workload. From the observation of workload data using the NASA-TLX method, a total of 170 questionnaires were given to workers who were in activities on the critical path, and the results of processing the mental load data the NASA-TLX score
average was 63.37, which according to [7], the value is included in the criteria "Max". Based on Table 2, the indicator that has the highest value is Temporal Demand (TD) and the indicator with the lowest value is frustration level. Temporal Demand Indicator shows how much time pressure is felt by the worker in completing the task. The observation shows that in every major inspection overhaul there are always ideas that arise from the operations director, General Manager (GM) and production manager to reduce the duration of the overhaul, these demands are of course a burden and responsibility of employees of PT. PJB UPHT as maintenance executor outage, in carrying out the overhaul of work performed generally not only a standard job. But often many additional jobs are found. Whereas there is additional work at the time of execution, the duration that has been given is difficult to be revised for additional time, so that these conditions put pressure on employees of PT. PJB UPHT. While the lowest indicator, frustration level describes feelings of insecurity, despair, irritability, stress during the work. This is because in overhaul work there are operational standards of work (SOP) that have been well designed, such as work instructions, use of personal protective equipment (PPE), giving breaks (coffee breaks). In addition, for work with heavy physical drainage, such as turbine disassembly of casing and compressor casing, the coordinator provides time allowance, so workers do not feel depressed.

| No | Category                | Average (Rating x Weight) |
|----|-------------------------|---------------------------|
| 1  | Mental Demand (MD)      | 161.43                    |
| 2  | Physical Demand (PD)    | 150.48                    |
| 3  | Temporal Demand (TD)    | 251.43                    |
| 4  | Performance (OP)        | 182.62                    |
| 5  | Frustration Level (FR)  | 40.24                     |
| 6  | Effort (EF)             | 164.29                    |
|    | WWL                     | 950.48                    |
|    | Average WWL             | 63.37                     |

Meanwhile, indicators of performance, effort, mental demand, and physical demand are in the order of 2, 3, 4, and 5 respectively. Performance categories indicate the level of success and satisfaction in completing work. The average job with a high level of performance is quality control. This is because quality control work requires the accuracy of the process and results of work so that the parameters are in accordance with the provisions made by the manufacturer, if in the process there are errors or incorrect calculations will result in rework work and if the process is not monitored then if it occurs errors at the start of the unit will be difficult to find the root of the problem, the reputation of the employees of PT. PJB UPHT will decline in the eyes of consumers.

The effort indicator shows how much effort is spent mentally and physically needed to achieve worker performance. In undergoing overhaul work that varies greatly with problems and obstacles, employees of PT. PJB UPHT feel they have to devote enormous effort to be able to condition the problems and obstacles that arise.

The Physical Demand (PD) indicator shows the need for physical activity at work. All work carried out during an overhaul always involves physical activities, such as removing turbine casing insulation, disassembling turbine manholes, and so on. This type of work does not suit for employees of PT. PJB UPHT who are generally less reliable in physical activity. However, these shortcomings can be overcome by utilizing outsourcing staff. Mental Demand (MD) is the second lowest indicator that shows the demands of mental and perceptual activities needed in work, such as thinking, deciding, counting, remembering, seeing and looking. This is because the type of work is usually done by employees of PT. PJB UPHT and is the main responsibility.
3.3. Analysis of Work Sampling vs Mental Workloads

Based on the aforementioned analysis, the effort factor perceived by outsourcing workers is a major element that is burdensome in the major overhaul of gas turbine inspection. Meanwhile, the temporal demand is felt by employees of PT PJB UPHT. Thus, the value of a high mental workload is not directly proportional to the results of the work sampling that has been obtained. The feasible solution could be provided for example using new technologies such as bolt induction heater when disassembly-reassembling the turbine casing and compressor casing so that it can reduce the time and effort spent. As well as laser technology used in generator rotor alignment process since using conventional methods requires very long duration and poor accuracy compared to the use of laser alignment.

3.4. Financial Study

In an overhaul of costs incurred consists of 2 types, namely the budget for material / consumable costs and services. In the implementation of the overhaul carried out by PT. PJB UPHT, the position from Project Manager (PM) to field coordinator will be filled by organic employees of PT. PJB UPHT. However, in the executor's position, the organic workers of PT. PJB UPHT will be assisted by outsourced employees. Procurement of outsourcing services is included in the service category, where in a major inspection overhaul, 126 outsourcing workers are needed covering Occupational Health and Safety (OHS), control planning, engineering, facilities, workshops, electricity services, transportation, warehouses, instrument control, mechanics and electricity. In the contract between PT. PJB UPHT and PT Mitra Karya Bersama (MKP) as a supplier of bulk labour services, contract costs worth IDR 1,951,974,816 for the allocation of 126 workers for 32 days, so that if there is work outside of the job standard and requires additional workers, the value offered is worth IDR 387,584 for 1 worker per day.

In the overhaul with the existing scheme, the major inspection is scheduled for 32 days, and based on the results of work sampling analysis and standard time determination, by using the Microsoft project, the completion of major inspection can be done for 28 days so that the acceleration is 4 days using a commercial calculator owned by PT. PJB by accessing www.mobiltangguh.ptpjb.com/niaga/, it will be obtained from the realization of the EAF profit of IDR 770,376,615.28.

Whereas if a 2 shift pattern is applied, the overhaul of the major inspection scope will be 18 days, thus shortening the time for 13 days. Then by using a commercial calculator that is owned by PT. PJB by accessing www.mobiltangguh.ptpjb.com/niaga/, it will be obtained from the realization of the EAF profit of IDR 2,696,318,099.74 But the profit must still be recalculated with the addition of services outsourcing on the application of 2 shift work patterns in the amount of IDR 195,342,336 so that the net income obtained is IDR 2,500,975,763.74.

Based on the results of the risk management document study made by PT. PPB UPHT to procure investment in induction heater bolt heater with an investment value of IDR 4,906,913,000 and laser alignment with an investment value of IDR 403,631,000, the total investment needed for the procurement of these items is IDR 5,310,544,000, so only three major inspection overhauls are needed to be able to get a break even point from procuring an investment in bolt heater induction heater and laser alignment.

4. Conclusions

Value added, necessary, non-value added, and non-value added activities are well matched, where the percentage of value added activity is 38%, necessary non-value added is 51% and non-value added is 11% of the total overhaul. Necessary non value added activities consist of 59% flushing oil, 16% bolt heating, 7% hauling activity, tool preparation and personal protective equipment, 4% alignment preparation, travel from the tool box to each 3% work position and other activities by 4%.

The indicator of outsourcing workers showing the highest value is the effort indicator (EF) and the lowest value indicator is frustration. The indicator of PT PJB employees who shows the highest value is the indicator of temporal demand (TD) and the indicator with the lowest value is frustration.

The high workload index is not directly proportional to this value added activity because of the high value of necessary non-value added. To minimize necessary non-value added activities and reduce the
level of mental burden of workers, new technology investments such as bolt induction heater, laser alignment, and rejuvenation tools are needed.

There is the potential to shorten the duration of the major inspection overhaul changes to work schedules from those originally scheduled for 32 days, to only 18 days by using the 2-shift pattern. The profit earned from shortening the duration of a major inspection overhaul to 28 days is IDR 770,376,615.28. The profit earned from the two shift application gets a shortening of the duration of a major inspection overhaul to 18 days is IDR 2,500,975,763.74.

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