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Research paper

The effect of efficiency measurement to the improvement of maintenance productivity

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Abstract

Industrial revolution from manual process to automation, digital, integrated between system make changing of demand on the performance of machinery or equipment. Efficiency and productivity are no longer calculated based on the output generated by the operators working in a process. Efficiency and productivity are calculated from the output of a machine or process that is integrated automatically. The need for regular maintenance of machinery or equipment is one of the main needs of manufacturing. In addition, the need for maintenance work is also a major concern. Performance of maintenance is not only measured from OEE (Overall Equipment Effectiveness) but also measured by the efficiency of their activity. Identification of Non Added Value (NVA) activity related to maintenance activity should be done to see improvement opportunities. In the end of investigation, we can increase efficiency from 20.4% to 49,5% by reduce NVA activity. From data of efficiency, we can calculate the number of maintenance personnel required, from 6 people to 4 people. This research to avoid shortage or excess man power resulting and impacted to decreased of efficiency and productivity for both the machine and the maintenance itself.

Keywords: *Maintenance Activity; Efficiency; Non Added Value Activity.*

1. Introduction

Along with the fourth generation of industrial revolution, marked by the emergence of supercomputers, smart robots, drivers less vehicles, genetic editing and development of neurotechnology that allows humans to further optimize brain function. Changes also occur in manufacturing. Production processes and information are manually managed, turning toward to automation and digital. Productivity and efficiency are no longer judged by operator activity, but also from machines. Even for a full automation process, productivity and efficiency measurements are based on machine performance. This leads to a change in the need for maintenance skills that perform maintenance ofthe automatic machines. They must adapt to the changing manufacturing technology. Every machine requires different treatments. The more variations of engine, both in terms of brand and function, will cause variation in the treatment, variety of spare parts, skills, time required for the maintenance of the machine. To calculate time required for maintenance, we need to know detail of task required for each machine.

At that time efficiency maintenance activity is not the part of noticed by the company. The new company started to conduct OEE measurements and focus on performance of machine. The demand for additional maintenance personnel makes the company think to measure the efficiency of maintenance activity. This research was conducted in order to determine the suitable tools to measure the efficiency of maintenance activity. The author starts the research by collecting all the maintenance activities, clustering into 2 parts of Non Added Value Activity (NVA) and Added Value Activity (VA), making check sheet that must be filled by maintenance. Data from this check sheet can be used to review the efficiency of maintenance activity. Constraints from this research is the discipline of maintenance in filling time sheet. Data collection not accurate and impact to wrong action plan to be taken by maintenance team.

2. Literature review

López et al do research on "Time measurement of maintenance task" [1]. Maintenance work time measurement can be transformed into two aspects :

1) Time measurement of the maintenance therbligs : determine the basic time of maintenance therbligs. It has no relation to the product and has a certain generality.
2) Layer design based on maintenance process : decomposing the maintenance process according to layering thought, bottom-up building, then the maintenance process can be decomposed into a series of sequential therbligs. Then, we add the maintenance therbligs layer into the traditional decomposition of the maintenance process. Finally decompose maintenance process into 4 layers: maintenance event layer, maintenance work layer, basic maintenance operation layer and maintenance therbligs layer (Fig. 1).

Grigoras et al consider about people management to measure efficiency of maintenance in steel making industry [7]. Kern write about implementation of lean operation to increase efficiency of maintenance facilities in Fedex Express [8]. Utilization of mobilizing CMMS/EAM to reduce extra hours to work on equipment and move reactive maintenance to proactive or predictive maintenance [16]. Dunn explain about Total Maintenance Man Hours or Wrench Time is percentage of time that direct maintenance workers are advancing completion of a

maintenance task [3]. Includes time spent using tools, excludes idle time, planning, traveling, transporting, securing information, etc. This is indicator of overall maintenance management effectiveness. Peter try to identify some time attribute does not include in wrench time [13]:

1) Running/traveling from emergency to emergency in a reactive, fire fighting mode
2) Waiting on parts and finding parts or part information
3) Waiting on other asset information, drawings, repair instructions, documentation, etc
4) Waiting for the equipment to be shutdown
5) Waiting on rental equipment or contractor support to arrive at the job site
6) Waiting on other crafts to finish their part of the job
7) Traveling to/from job site
8) Make ready, put away, or shop cleanup time
9) Meeting, normal breaks, training time, and excessive troubleshooting due to lack of technical skills
10) Lack of effective planning and scheduling

Research by Efleck at al explain that maintenance optimization is an analytical process that can be used to [5]:

1) Determine the optimum set of maintenance task to be performed on systems and equipment
2) Document the basic for each task. An optimum set of maintenance task depends on many factors, some usually not thought of as drivers for the performance of maintenance. This process is not a one shoot deal, it is a living process that allows for continual improvement in maintenance program efficiency as better monitoring, measurement, and maintenance tools become available

From the reviewed literature, to see the efficiency of maintenance activity, we need to define a method to see all their activity. With manual process change to automation process, then the demands on maintenance to review efficiency and productivity throughout their activities will be occur. The purpose of carrying out this research is to develop a method to review entire maintenance process and the method should be able to provide recommendation action plan that brings them towards increased efficiency and productivity.

Slaichova et al explain about the effect of implementing a maintenance information system on the efficiency of production facilities. They use computerized maintenance management information system (CMMIS) to get the result from data analysis [15].

Based on finding from data analysis, they suggest some managerial targets for achieving better performance can be set as follow :

1) Decrease number of downtime, data analysis can show us categorization of downtime
2) Increased utilization of OEE metrics (Overall Equipment Effectiveness) : availability, performance and quality
3) Decreased cost of production and maintenance – calculating the cost of machine breakdown
4) Increased working time
5) Implementation of regular maintenance check
6) Stabilization of production processes which includes several aspects like setting standards of production time, standard for machine adjustment and changeover of the tools

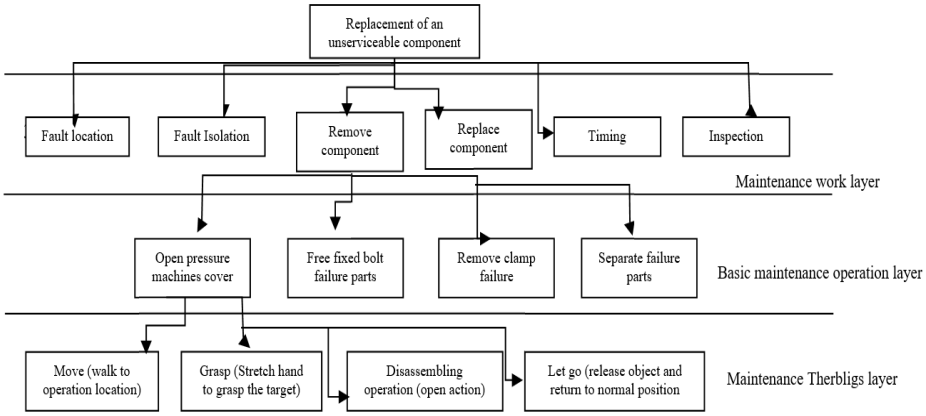

Fig. 1: Four Layer Maintenance Process

There are many methodologies and tools used to improve the efficiency of a department or company. But most of them use Lean methodology. In research conducted by Rajenthirakumar and Harikarthik, they use VSM (Value Stream Mapping) to identify waiting time before process, setup time, process time, waiting time after process and transfer time [14], and also confirmed by the study of Purba et al [18]. One of the action plans that they do in order to improve efficiency in construction equipment manufacturing company is a prepared standard work sheet [14]. While in research Kocakulah et, they use standard work and worker involvement to increase efficiency [9]. Kreneva at al. use 5S to improving the efficiency of agricultural enterprises [10]. Panwar et al trying to prove that lean practice can improve performance in Indian process industries [12]. Erkoyuncu et al demonstrates to improve the maintenance efficiency through adaptive operational support using a context aware Augmented Reality (AR) technique that adapts with available data and the skill level of the technician and without the need for prior working knowledge of AR [4]. Arslankaya et al research to described the implementation of maintenance management and lean manufacturing techniques at the maintenance workshop in order to eliminate the losses due to breakdowns [2]. Mourtzis et al present the development and testing of an Augmented Reality remote maintenance platform to increase efficiency of the of the maintenance procedure and reduce required maintenance time [11]. Garza-Reyes et al research about the effect of lean methods and tools on the environmental performance of manufacturing organization [6]. In this research, author want to see the actual wrench time and identify what kind of non added value activity in manufacturing company, especially maintenance activity in site. Data collection from all activity can guide us to identify potential improvement in maintenance team. In addition, the breakdown of the list of tasks for each machine indirectly provides standardized AM and PM processes for all machine operators and maintenance teams. Whoever does the AM and PM process, they will do the same activity. During this time maintenance or machine operators do AM and PM based on their respective experiences. The process sequences in the AM and PM list of tasks will determine their activity efficiency.

3. Methodology

In this study, the author conducted a research of any activity undertaken by the maintenance team at a manufacturing company. There are 3 (three) current maintenance activities, Autonomous Maintenance (AM), Preventive Maintenance (PM) and Reactive Maintenance (RM). All AM activities are performed by the machine operator who working on the machine. Maintenance team only makes check sheet and work instruction as guidance operator when doing autonomous maintenance.

In the early stages of the study, the authors perform the following methods in collecting data related to maintenance activities :

1) Observe the activities of one of maintenance team both when he doing preventive or reactive maintenance and other activities.
2) Record all of these activities.
3) Grouping all activities into 2 (two) category : Value Added (VA) and Non-Value Added (NVA) activity. Category of VA is all maintenance activities related to PM and RM. VA activity begins when tools used for PM or RM already in the hands and maintenance stand in front of the machine or equipment. All preparation activities and activities after PM or RM will be included into NVA category.

Category of NVA activity :

1) Briefing : coordination meeting every beginning of shift.
2) Coffee break : break 15 minutes for every shift.
3) House keeping : usually used at the end of a shift to clean the area or workbench, keep tools or equipment in place.
4) Training : follow the training both for improving technical skills and management skills.
5) Waiting : waiting spare part, instruction, etc.
6) Tools preparation : preparation tools for PM or RM.
7) Travel : travel from one area to another area, for example from tools room to workshop.
8) Administrative : recorded activities both for historical purposes and for VA and NVA activities.
9) Looking for spare part : searching spare part for PM and RM.
10) Check historical data : searching historical data for the reactive maintenance purposes.
11) External repair : waiting RM or PM conducted by external parties.

Category of VA activity :

1) Repair : reactive maintenance activity is calculated when tools are already in hand until machine back to normal condition.
2) Preventive Maintenance : preventive maintenance activity is calculated when tools already in hand until machine back to normal condition.

Table 1: Sample of Manual Time Sheet for Maintenance

Time Sheet Maintenance
Name : Operator B Date : 3 march 2018 Shift : Day Shift
ID : 111112

JOB No	Code VA/NVA	Job Desc	Time (Minutes) Start	Finish	Std	Act	Remarks
-	1510		07:30	07:45			Non Value Added : 1510 : Briefing
A 12 12 12 12 12	1580	PM Welding Machine 1	07 :4 5	07 :5 5			1520 : Coffee Break
A 12 12 12 12 12	1590	PM Welding Machine 1	07 :5 5	08 :1 5			1530 : House Keeping
A 12 12 12 12 12	1560	PM Welding Machine 1	08 :1 5	08 :3 5			1540 : Training
A 12 12 12 12 12	1620	PM Welding Machine 1	08 :3 5	09 :4 5			1550 : Waiting
A 12 12 12 12 12	1520	PM Welding Machine 1	09 :4 0	09 :3 0			1560 : Travel
A 12 12 12 12 12	1620	PM Welding Machine 1	09 :3 0	10 :4 0			1570 : Administrative
-	1530		10:30	10:35			1580 : Tools Preparation
							1590 : Looking for Spare Part
							1600 : Check Historical Data
							1610 : External Repair
							1620 : PM / Trouble shoot

Added Value Activity Approved By
I : Reactive Maintenance
II : Preventive Maintenance

After the author determined the VA and NVA groupings, the authors used different methods of collecting data to see the overall efficiency of the maintenance team. The method using a check sheet for the collection of information (Fig. 2). The details of this method are as follows:

1) To collect data on all activities performed by each maintenance personnel, the author makes a check sheet that will be filled by maintenance team.
2) Socialize how to fill the check sheet. Socialization was done 2 times because the maintenance team worked in 2 shifts (day shift dan night shift).
3) Collect check sheets filled by maintenance.
4) Insert check sheet data into the database, in this case the author still uses excel file

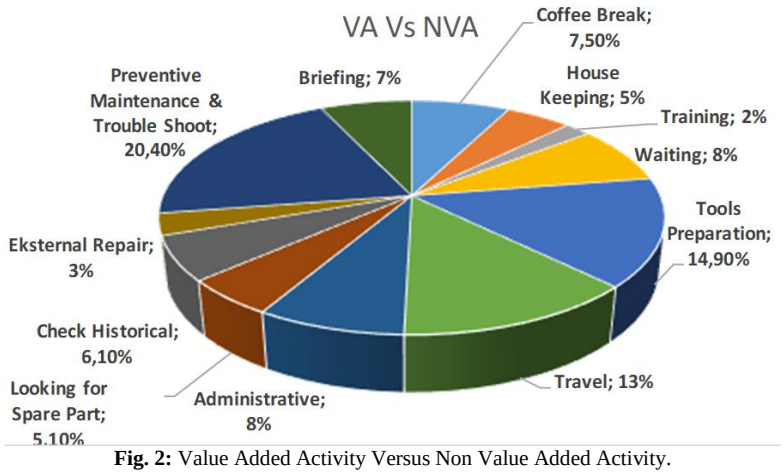

Fig. 2: Value Added Activity Versus Non Value Added Activity.

In this study, the authors found the real time used to do RM & PM is only 20.4%. The remaining time of 79.6% is used for tools preparation of 14.9%, travel by 13%, waiting 7.9%, administrative 7.7% and others (Fig 3). This NVA classification can be used to improve one of the maintenance performance, ie efficiency improvement. By this data, we can identify which one from NVA as a priority to be minimized or even eliminated. For example, administrative activities of 7.7% resulting from requests by authors to collect data can be minimized by using barcoding systems, maintenance teams no need to write all their activity into the time sheets and put them into the database. With a barcoding system, maintenance simply scans the barcodes associated with their activity and the data is automatically saved into the database. The point in this paper is the authors want to emphasize that the classification of VA and NVA in the maintenance activity needed to see how efficient the time used maintenance team in doing their activity. In addition to improving maintenance efficiency, this data can also be used to help calculate the number of required maintenance personnel. Table 1 shows an example of the activity and estimated time required to perform maintenance on a machine. Details of this activity are needed to see how much time it takes to perform regular maintenance of the machine, either daily maintenance (autonomous maintenance), weekly, monthly, quarterly, semester or yearly maintenance. Need to collect data from all machine to know total time needed to maintain all machines.

Table.2: Sample Maintenance Activity Including Estimation Time for Each Activity

Maintenance Level	PM Task List	Estimated Workload	Frequency	Monthly Workload
Level 1	Cleaning Machine	15,0 Min.	Daily	390,0 Min.
Level 1	Check pressure gauge and leakage in lubricating pipe	1,0 Min.	Daily	26,0 Min.
Level 1	Check Lubricating oil level in front of base (Use BP ENERGOL GRXP150)	1,0 Min.	Daily	26,0 Min.
Level 1	Check oil level. It placed on glass sight in the tank (Use CAT HYDRAULIC OIL)	1,0 Min.	Daily	26,0 Min.
Level 2	Check Pressure Oil	15,0 Min.	Monthly	15,0 Min.
Level 2	Check and adjust taper gibs slide ways X axis	20,0 Min.	Quarterly	6,7 Min.
Level 2	Check and adjust taper gibs slide ways Y axis	20,0 Min.	Quarterly	6,7 Min.
Level 2	Check and adjust taper gibs slide ways Z axis	20,0 Min.	Quarterly	6,7 Min.
Level 2	Replace hydraulic oil	60,0 Min	Semesterly	10,0 Min
Level 2	Replace coolant	60,0 Min	Semesterly	10,0 Min
Level 2	Replace Oil gearbox	60,0 Min	Semesterly	10,0 Min

$$A = \sum \text{(Estimate Workload Weekly x 4)} \quad (1)$$

$$B = \sum \text{Estimate Monthly Workload for Monthly frequence} \quad (2)$$

$$C = \sum \text{(Estimate Workload Quarterly / 3)} \quad (3)$$

$$D = \sum \text{(Estimate Workload Semesterly / 6)} \quad (4)$$

$$E = \sum \text{(Estimate Workload Yearly / 12)} \quad (5)$$

$$\text{Monthly Workload for PM} = A+B+C+D+E \quad (6)$$

4. Result

Basically every machine has a manual book as our guide in doing AM or PM. However, in this research a lot of machines dont have manual book so that the author and maintenance team does not have a reference in determining the PM activity. In order to keep running PM activities and every activity can be measured his efficiency, the authors brainstorming with team maintenance and using historical data as additional reference. The following methods used by the author in retrieving data to get total workload maintenance in doing PM is as follows :

1) Together with maintenance team to identify what kind of activities need to do during preventive maintenance process in each machine.
2) Divide maintenance activity become 2 level. Level 1 is maintenance activity undertaken by operator or we can call Autonomous Maintenance (AM) and level 2 is all maintenance activity undertaken by maintenance team.
3) Create PM task list for each level.
4) Create estimated time for each task.
5) Identify frequent checking (daily, weekly, monthly, quarterly, semesterly or yearly).
6) Due to author need to analyze total workload per month, then the author divide all workload into monthly workload.

After getting the total workload from all machines, we can use it in calculating the number of man power needed. Here is the formula to calculate number of maintenance:

$$\text{Total Monthly Workload for PM} = \text{Monthly Workload for PM} \times (100\% + \text{Target VA}) \quad (7)$$

$$\text{Number of Maintenance Needed} = (\text{Total Monthly Workload for PM} + \text{Target Monthly Workload for RM}) / (\text{Number of Day per Month} \times \text{Available Hours per Shift}) \quad (8)$$

Where,
Target Monthly Workload for RM is one of the KPI to increase productivity of maintenance team.

Table 3: Sample How to Calculate Available Time of Maintenance Team

Available Time Maintenance Team Head Department : Operator A						
No	Name	Available Time / Day	Available Day / Week	Weekly Hours	Available Day / Month	Monthly Hours
1	Operator B	8	5	40	22	176
2	Operator C	8	5	40	22	176
3	Operator D	8	5	40	22	176
4	Operator E	8	5	40	22	176
Total Available Time / Month (Hour)						704
Total Available Time / Month (Minutes)						42240

Below is sample of calculation number of man power for maintenance. Table 3 show to us how to calculate total available hours. In this company, they have 4 operator maintenance with available time is 8 hours per day and 5 days per week.

$$\text{Available time per month} = \text{Available time per day} \times \text{Available day per month} \times \text{available man power} \quad (9)$$

= 8 hours x 22 days x 4 operator

= 704 hours per month

= 42240 minutes per month

Table 4: Time Consumption for PM

Time Consumption for PM					
Time	Weekly PM	Monthly PM	Quarterly PM	Semesterly PM	Yearly PM
Hours	9.5	197	82	143	54
Minutes	570	11820	4920	8580	3240
Monthly Workload (Minutes)	2280	11820	1646.67	1429.5	270
Total Monthly Workload (Minutes)				17448	
Total Monthly Workload for PM with VA 35% (Minutes)				28789	

Assumpt that:

1) Target of Monthly Workload for RM is 30% from Total Available Hours, it's mean :

Monthly Workload for RM = 30% x Available Time

= 30% x 704

= 211 hours or 12660 minutes

2) Target VA Monthly Workload for PM is 35%, it's mean:

Total Monthly Workload for PM = Monthly Workload for PM x (100% + Target VA)

= 17448 x (100%+35%)
= 28789 minutes

Time needed for PM and RM = 12660 + 28789

= 41449 minutes

Gap between Available Time Vs Time Needed

= 42240 – 41449

= 791 minutes or 13 hours

Number of Maintenance Needed = (Total Monthly Workload for PM + Target Monthly Workload for RM) / (Number of Day per Month x Available Hours per Shift)

= (12660 + 28789) / (22 x 8 x 60)

= 3.93 people or 4 people

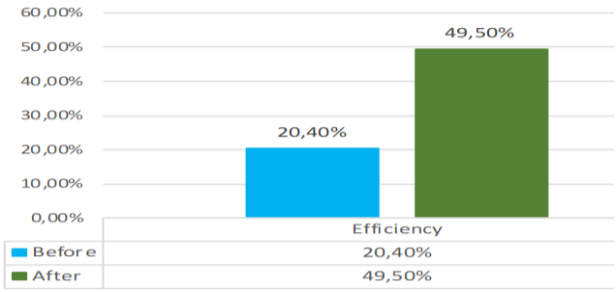

Fig. 3: Comparison Between Before and After Implementation of Measurement Efficiency of Maintenance Activity.

Figure 3 show the improvement of added value activity after implementation of measurement efficiency. Increasing efficiency around 29%, it's mean maintenance can put additional machine or equipment into PM list due to they have additional time around 29% from previously or they can reduce number of people in maintenance team.

Reduce Number of Maintenance Team= (Actual Number of Maintenance Team - Number of Maintenance Needed) (10)

= 6 people - 4 people

= 2 people

Figure 4 show the improvement of reduce some non added value activity after implementation of measurement efficiency. The biggest improvement is tooling preparation and traveling. This improvement come from standardize task list. They know what they have to do during PM and they prepare all tools needed before they start to do PM.

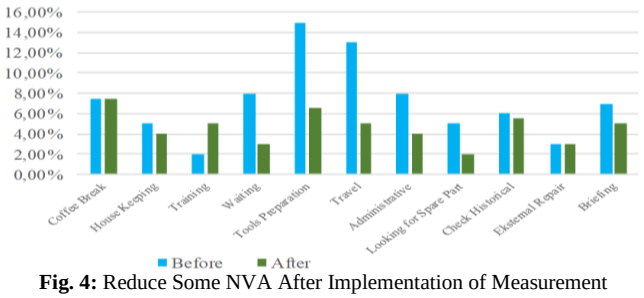

Fig. 4: Reduce Some NVA After Implementation of Measurement Efficiency.

Additional benefit from efficiency measurement as follow :

1) Company have basic data as based line to do improvement
2) More easy to identify priority area for improvement
3) Standardize task list both for AM and PM
4) Increase productivity of maintenance by increasing efficiency and regular review standardization of task list
5) Increase productivity of production due to they have additional time from decreasing time AM and PM

Benefit from Maintenance = Increased efficiency x available hours of maintenance team per month (11)

=29.1% x 42240 minutes per month

=12291 minutes per month

5. Conclusion

Measure efficiency of maintenance activity is one way to see maintenance performance. All data from efficiency can help us to identify priority of improvement. We also can use this data to calculate man power requirement. To improve data collection for efficiency, author suggest to change manual time sheet to barcode system. You can create barcode for each NVA and VA activity (Fig. 5). This is the way to increase efficiency of maintenance and accuration of efficiency data.

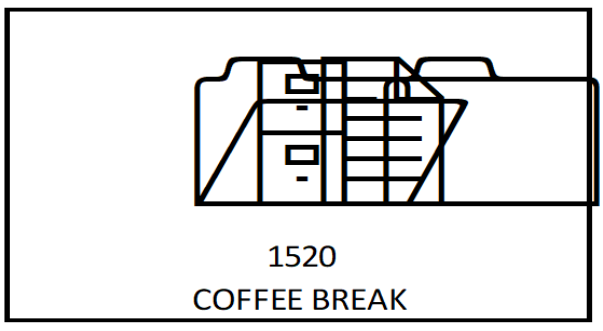

Fig. 5: Sample Barcode for NVA Coffee Break.

Data from efficiency is the basic data that can be used to calculate the man power required, trigger action plan to eliminate existing NVA, visual control for tooling, effective PM schedule, effectiveness meeting in the beginning of shift, etc. When a company has evolved toward automation, efficiency maintenance becomes crucial because performance production is highly dependent on their performance. Increased efficiency maintenance will be impact to increased capacity of production. Measurement methods to measure maintenance efficiency can be done in the field of any industry, both the manufacturing or service industries. The different is the NVA classification only. The more detailed NVA classification, the easier to analyze and determine the priority of improvement. There are many ways in the NVA data retrieval process, either by manual, semi auto (barcode) or with other digital systems. Currently there are many digital system that can be used for data collection process. What needs to be taken into account in making decisions about the system used is the level of needs and budget company. The most important is the follow-up action plan that must be done to improve efficiency maintenance. Usually the main constraint in the early measurement of maintenance efficiency is the maintenance discipline to filling activity into time sheets or scan the barcode, and then followed by NVA and VA data analysis. Try to reduce manual administrative because they do not like to do that. Providing training on the benefits of efficiency measurement and finding the moment to demonstrate the evidence of these benefits will be greatly assist in the continued completion of VA and NVA data. Sharing about the benefits of efficiency improvement is not only done by the maintenance team but also in some related departments such as PPIC, production and supply chain. In the supply chain department, they have an important role to make sure the availability of spare parts for PM activity. While in PPIC and production, they must know that with the increasing of efficiency it will bring impact to the increase of production capacity.

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