UDC 338

WASTE LEVEL ANALYSIS IN A CARE SECTION WITH THE LEAN MAINTENANCE METHOD TO MINIMIZE WASTE IN PT. VARIA USAHA BETON GRESIK

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ABSTRACT
The major problem faced by PT. Varia Usaha Beton Gresik is not the maintenance activity according to Standard Operation Procedure (SOP), but the activities conducted without taking into account the waste. The purpose of this study is to examine the waste in the maintenance activities as to minimize it by the lean maintenance method. This is taken on a conveyor belt weigher machine, a bucket conveyor, a concrete mixer, and a machine host. The variable is the flow of treatment by reducing waste and by giving recommendation of improvement. Data collection includes damage data, production data, product disability data, and maintenance activity data. The conclusion is QT-10 waste motion machine takes 532 minutes for waste repair, 45 minutes for waste process, and 90 minutes for waste waiting. Our recommendations include improvement on the information provided, on training and rewards, and on supervisors of the production line.

KEY WORDS
Lean maintenance, value stream maintenance mapping, reduce waste, equipment effectiveness, Root Cause Analysis.

The manufacturing process in the manufacturing industry will face competition in the increasingly stringent industrial world requiring every company to work even harder to win the very fluactive market. The production process requires itself needs to be more productive and efficient. The manufacturing industry nowadays almost all uses modern machinery and equipment. According to Siringoringo and Sudiyantoro (2004), more and more machinery is used to meet production targets which sometimes exceed the capacity of the machinery itself; this, finally reduces the life of the machiney and makes replacement of damaged components become too often.

In the production process, damaged machines often disrupt the process. Maintenance activities at PT Varia Usaha Beton Gresik are in the forms of preventive maintenance and corrective maintenance. As a manufacturing company engaged in industrial and printing services in concrete in which the products are precast concrete, masonry and concrete, and ready mix. Based on the data in the production line of the company at the BM (Masonry Concrete) plant in 2016, the most often damaged machine is the QT-10. The damage often occurs in the production line of the belt weigher conveyor, the bucket conveyor, the concrete mixer, and the host machine.

The maintenance activity is good enough in accordance with the existence of Standard Operation Proccedure (SOP). However, the maintenance process does not pay attention to waste on. The method used in this study is the lean maintenance method, which is able to perform an analysis of the level of waste and at the same time to minimize waste in PT Varia Usaha Beton Gresik.

LITERATURE REVIEW

Definition of Maintenance. In his book about the factory maintenance management with ergonomic approach Gempur Santoso (2010) states that maintenance is a process that studies and determines the actions necessary to prevent the same damage to happen.

According to Assauri (2000), maintenance is an activity of factory facilities to make necessary repairs, adjustments, or replacements in order to reach productivity as planned.

According to Corder (2002), maintenance is a collection or combination of activities to maintain and improve the ability of a device.

According to Ansori (2013), machine maintenance is basically divided into two parts, namely planned maintenance and unplanned maintenance).

The following is a description of each machine maintenance system:

Preventive maintenance. The maintenance activities undertaken to reduce the likelihood of occurrence of unforeseen damage and to find conditions or circumstances that cause the production facility to be damaged when used in production. This includes: Routine maintenance; Periodic maintenance; Running maintenance; Shutdown maintenance.

Corrective maintenance. This is done after the damage; so, it is part of unplanned maintenance or done when the equipment cannot function properly. Corrective maintenance activities cover all activities to restore the system to its good condition. This includes: Preparation time; Active maintenance time; Delay time and logistic time.

Lean. Lean's basic concept is an ongoing effort to eliminate waste and to increase the added value of a product or service to deliver customer values to customers (Vincent Gaspersz, 2007)

Lean Maintenance. Lean maintenance is defined as the philosophy of a maintenance activity that produces a preferred maintenance result using the least amount of input (Levit, 2008). To effectively achieve maintenance improvements, key lean tools are used in the lean manufacturing such as Value Stream Mapping (VSM) to assess existing circumstances, 5S for workplace organizations, visual and engineering management tools, and other tools (Hawkins.S 2004).

Lean maintenance cover six stages, as follows: Lean Assessment; Lean Preparation; Lean Pilot; Lean Mobilization; Lean Expansion; Lean Sustainment.

Equipment Effectiveness (E). Equipment Effectiveness (E) is a performance measure that primarily monitors the effectiveness of individual equipment, which does not depend on the operating environment. As a basis for measurement, Equipment Effectiveness utilizes the effective time available when compared to Overall Equipment Effectiveness (OEE) which uses the total time. Equiment Effectiveness is a real device metric that monitors equipment status by itself. OEE combines time losses due to the condition of independent equipment such as the lack of raw material input, of buffer space for improper scheduling settings, or operator unavailability. OEE measures the effectiveness of the equipment and its surroundings while E measures the effectiveness of certain equipment independent of its surroundings in the production line. In production lines, identical machines may have the same OEE while E may vary from one device to another.

METHODS OF RESEARCH

Location and Time of Study. This study was conducted at PT. Varia Usaha Beton Gresik, located at Jl. Veteran No.129A, Sidokumpul, Gresik District, Gresik Regency,. It was conducted in December 2016 until the data was completed.

Identification of Variables. Based on the research title, variables associated are as follows:

Dependent Variable. A dependent variable is a variable influenced by other variables (independent variable). Included in the dependent variable in this study is reducing waste and effectiveness levels of the type QT-10 machine.

Independent Variable. An independent variable is the decision variable to be sought. The independent variables in this study include the followings: Data damage (a belt weigher conveyor, a bucket conveyor, a concrete mixer, and a host machine); Production data; Product disability data; Maintenance activity data.

RESULTS AND DISCUSSION

Data Damage. The historical data of engine component damage used in this study is the data from January 2016 to December 2016. It deals with the level of damage of each section of the QT-10 machine. The total damage time of each part is presented in Table 1.

Table 1 – Machine Damage Data (1 year)

No	Name of The Machines	Damage Time (Minutes)
1	Belt Weigher Conveyor	1055
2	Bucket Conveyor	400
3	Mixer Concrete	655
4	Host Mechine	590
	Total	2700

The total overall damage time in a year for a QT-10 type paving machine is 2,700 minutes in a year.

Data processing: Assessment of Equipment Effectiveness. Assessment of equipment effectiveness is done from QT-10 machine on the existing condition of the machine. This assessment process requires the output product data from the QT-10 machine. The machine works for twelve hours in total; for shift work in the production, it works for six hours per shift. The results of production data for one day are calculated in Table 2.

Table 2 – Production Calculation Table (1 day)

No	Production Types	Hour/Ea	Kg/Ea	Kg/Hour	Kg/Day	Ea/Day
1	T-6 PAVE ABU-ABU K300	0.00036	3.25	9069.767	108837.2	33488.37
2	T-6 PAVE MERAH K300	0.00036	3.25	9069.767	108837.2	33488.37
3	PAVE T-6 K300	0.00036	3.25	9069.767	108837.2	33488.37
4	PAVE T-6 K400	0.00036	3.25	9069.767	108837.2	33488.37
5	PAVE T-8 K300	0.00036	4.15	11581.4	138976.7	33488.37
6	PAVE T-8 K400	0.00036	4.15	11581.4	138976.7	33488.37
7	PAVE T-10 K300	0.00036	4.15	11581.4	138976.7	33488.37
8	PAVE T-10 K400	0.00036	4.15	11581.4	138976.7	33488.37
9	TOPI USKUP T-6 K300	0.00083	5	6000	72000	14400
10	TOPI USKUP T-6 K400	0.00083	5	6000	72000	14400
11	TOPI USKUP T-8 K300	0.00083	6.2	7440	89280	14400
12	TOPI USKUP T-8 K400	0.00083	6.2	7440	89280	14400
13	PAVE T-6 K300 PERSEGI 21X21	0.00083	4.8	5760	69120	14400
14	PAVE T-8 K300 PERSEGI 21X21	0.00083	5.6	6720	80640	14400
					Total	354307
					$\bar{X}$	25307,6

From the calculation table (Table 2), changes in the production time data is done by looking for Ea per Day, as follows:

Example: (Pave T-6 K400 sample)

Hour/Ea= 0.00036

Kg/Ea= 3.25

Kg/hour= 3.25/0.00036 = 9069.77

Kg/day= 9069.77*12 = 108837.21

Ea/day = 108837.21 / 3.25 = 33488.3

From the sample type of paving T-6 K400 above, the same calculation is done for other paving types. Then the production capacity of machine QT-10 in one day is 25307.64 Ea per day = 25308 Ea per day.

Cycle Time. It is the time required to produce one component to convert the amount of paving produced by QT-10 machines from hours to days with an average of 25308 Ea products per day/12 hours = 2109 Ea/hour. Next time required for the production of one paving is 3600 seconds/2109 Ea = 1.70 seconds per paving.

Working Hour. The number of working hours in one year is as follows:

Working Hour = (Working Hour/Day * Working Hour/Month)
= (12 hours/day * 365 day on work)
= 4380 hour/year * 60 = 262800 minutes/year

Break Time. It refers to the number of stops in the production activity. The machine works 12 hours a day, and then it stops once a week of a five working day. So it can be concluded, that the machine has a break time of 2246400 seconds/year (52 weeks in a year, so there are 52 days break time, meaning 52 days x 12 hours x 60 minutes which equals to 37440 minutes/year or 2246400 seconds/year).

Breakdown Time. From table 1, the breakdown time of a machine for a one year period from January 2016 to December 2016 is 2700 minutes per year or 162000 seconds per year.

Effective Time (T_e). It is a total working hour for one year, which is is 262800 minutes/year or 15768000 seconds/year.

Productive Time (T_o). This represents the productive time by means of effective time subtracted by the breakdown time (262800 seconds/year or 2700 minutes/year) which equals to 260100 minutes/year or 15606000 seconds/year.

Actual Time. It is the time for the machine to work. The formula is as follows:
Actual Time = (*Productive Time – Break Time*)
= (260100 minutes/year – 37440 minutes/year)
=222660 minutes/year
=13359600 seconds/year.

The results from point number 1 to 7 above become parameters to be inserted to the machine effectiveness especially for the QT-10 machine. The calculation is as follows:

Calculating Total Products Manufactured (N)
N = (*Actual Time* / *Cycle Time*) = (13359600 seconds/year or 1.70 seconds/product)
= 7858588.2 products/year
= 7858589 products

Maximum Number of Products Can Be Produced (N_{max}):
N_{max} = T_e : *Cycle Time*
= 15768000 seconds/year : 1.70 seconds/product
= 9275294.11 products/year = 9275295 products/year.

Number of Qualified Products (N_Q):
N_Q= N – Deffect product
= 7858589 – 59480
= 7799109 products/year.

Table 3 – The Product Deffect per Kilogram (1 year)

Month	The Total of Deffect Product (Kg)
January	13220
February	6052
March	4231
April	2444
May	8365
June	432
July	845
August	3369
September	2190
October	2695
November	13117
December	2520
Grand total	59480

Table 3 shows the total of product deffect in a year multiply by every load of the product types.

Availability (A) = T_o : T_e = 260100 : 262800 = 0.9897.

Performance Effeciency (R) = N : N_{max} = 78585891: 9275295= 0.8472

Eqipment Effectiveness (E) = A x R x Y = 0.9897x0.8472x0.9924 = 0.8321 = 83.21%

From the calculation, the effectiveness of the equipment is 83.21%, which means that the activities can improve equipment performance.

Value Stream Maintenance Mapping. This refers to mapping of each maintenance process. From the selection of critical components classified as 80% in the pareto diagram, 24 components belong to a critical category. It will create a Value Stream Maintenance Mapping (VSMM). Then, one component of QT-10 will be mapped with VSMM as shown below:

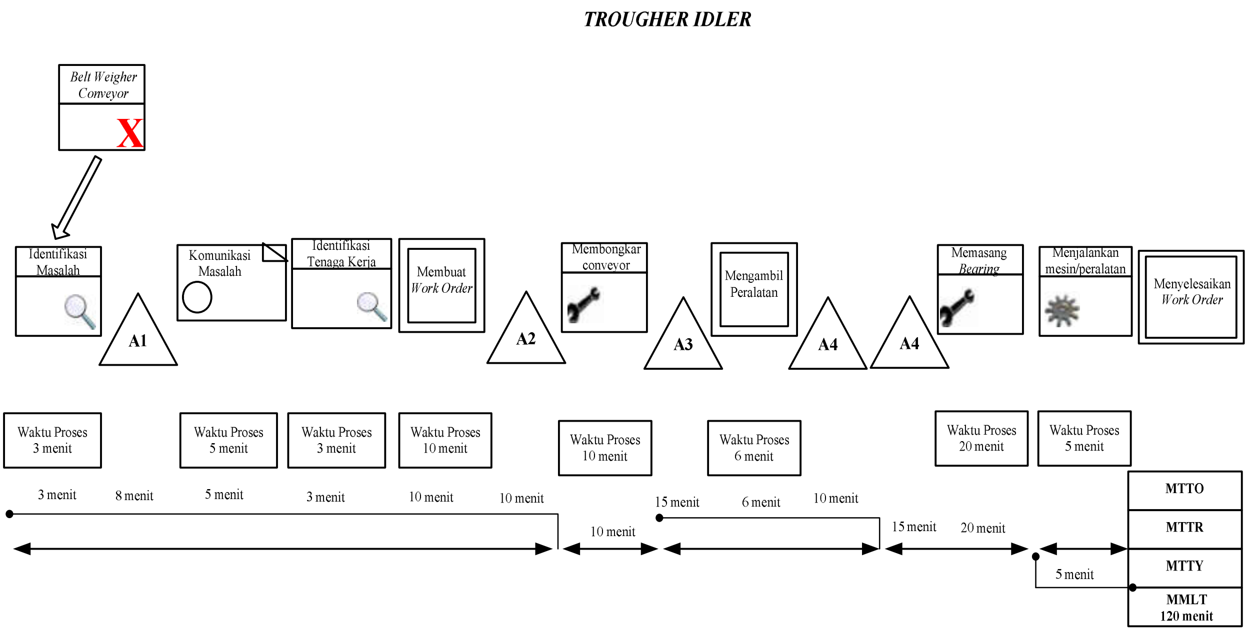

Figure 1 – VSMM for *Trougher Idler*

The Selection of Critical Components. The selection of the critical condition of components employs a Pareto diagram for each machine. For the QT-10 engine parts, the belt weigher conveyor, bucket conveyor, concrete mixer, and host machine are looked for critical condition.

The *Belt Weigher Conveyor:*

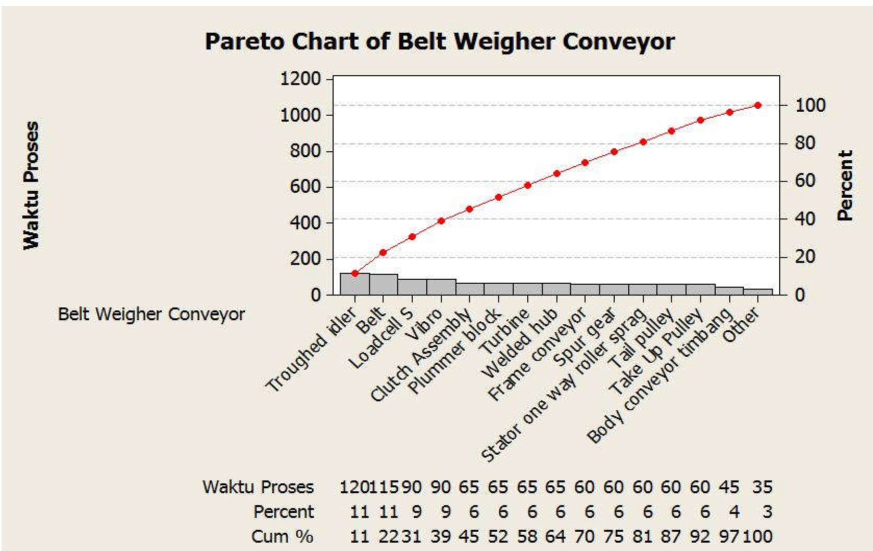

Figure 2 – The Pareto Chart of the Damaged *Belt Weigher Conveyor*

The result of cumulative frequency calculation shows that the improvement activities significantly affect the 80% parts of the repaired components, i.e. the troughed idler, belt, load cell, vibro, clutch assembly, plumeway block, turbine, welded hub, conveyor frame, and spur gear.

The Gear of the *Bucket Conveyor:*

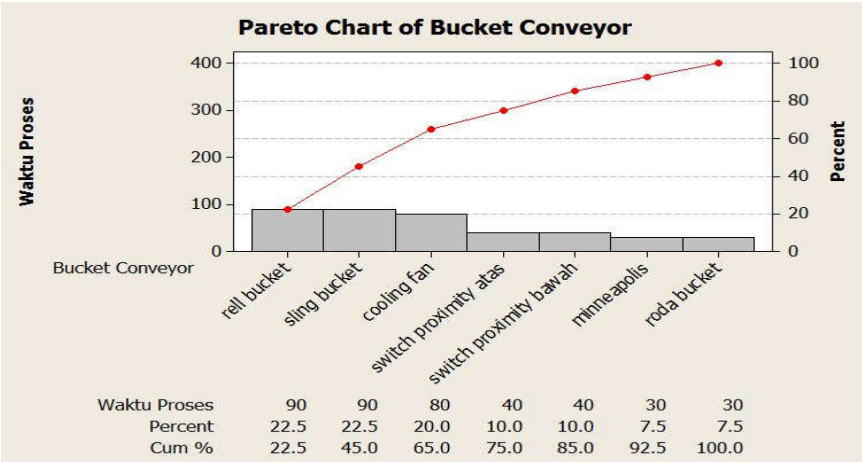

Figure 3 – The Pareto Chart of the Damaged *Bucket Conveyor*

The result of cumulative frequency calculation shows that the improvement activities significantly affect the 80% parts of the repaired components, i.e. the rell bucket, sling bucket, cooling fan, and upper proximity switch.

Concrete Mixer:

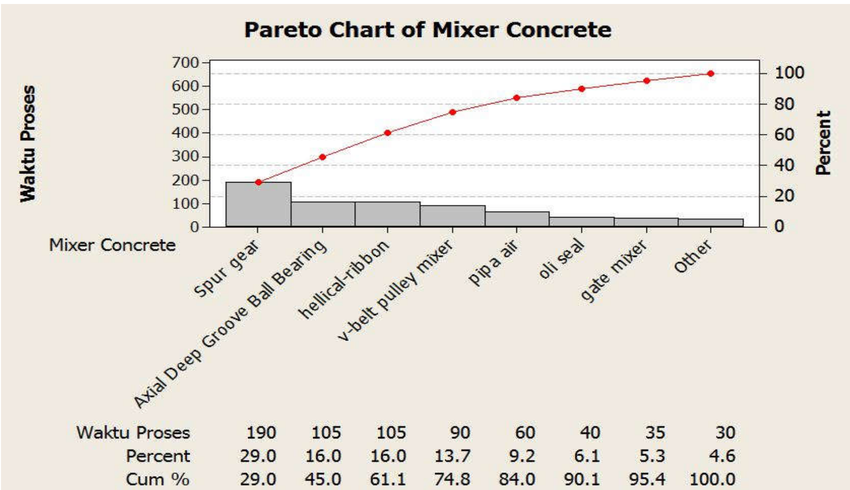

Figure 4 – Pareto chart of the damage of *Mixer Concrete*

The result of cumulative frequency calculation can be seen that the improvement activities that significantly influence the 80% part are component repair activities, namely Spur Gear, Axial Deep Groove Ball Bearing, Hellical-Ribbon and V-belt Pulley Mixer.

The *Host Machine:*

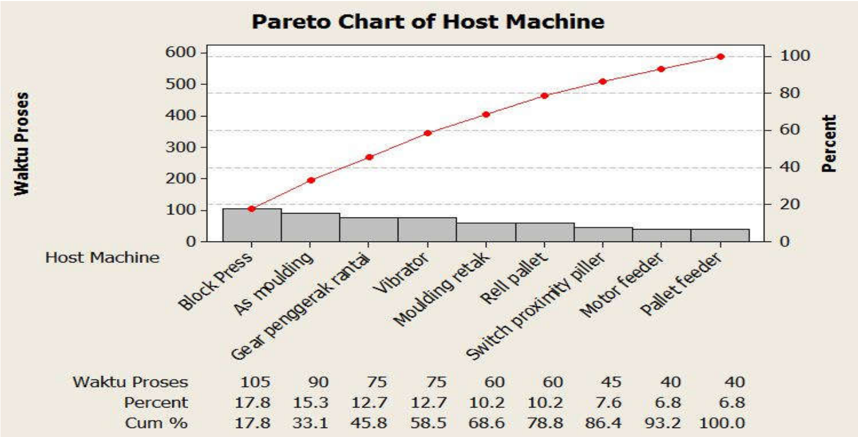

Figure 5 – The Pareto Chart of the Damaged *Host Machine*

The result of cumulative frequency calculation shows that the improvement activities significantly affect the 80% parts of the repaired components, i.e. the block machine, molding, gear drive chain, v-belt vibro, molding crack, and rell pallet.

Waste Identification. In the maintenance activities of any damaged components, we use Value Stream Maintenance Mapping (VSMM); it describes maintenance activities to determine the unplanned delay. The function of identifying the classified waste in the lean maintenance is as follows:

Table 4 – The Type of Waste on Critical Maintenance Activities

Components	*Waste*	Code	Activities	Time (minute)	Time (second)
Trought Idler	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
	Process	3	The maintenance worker identifies the problem	15	900
	Motion	4	The maintenance officer heads to the production head to take part	10	600
		5	The production floor continues the improvement	15	900
Belt	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
	Process	3	The maintenance worker identifies the problem	10	600
	Motion	4	The maintenance officer heads to the production head to take part	10	600
Belt	*Motion*	5	The production floor continues the improvement	15	900
Vibro	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Loadcell S	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Clucth Assembly	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Plummer Block	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Turbine	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Welded Hub	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Frame Conveyor	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
		3	The production floor continues the improvement	10	600
Spur Gear	*Motion*	1	The operator reports the damage to continue WO	8	480

		2	The maintenance officer heads to the production floor where the damage happens	10	600
Rell Bucket	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
	Process	3	The maintenance worker identifies the problem	20	1200
	Motion	4	The production floor continues the improvement	10	600
Sling Bucket	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Cooling Fan	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Switch Proximity Atas	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Spur Gear	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
		3	The maintenance officer heads to the production floor where the damage happens	10	600
	Waiting	4	Waiting for authorization from the plant head	20	1200
		5	Waiting for the part	70	4200
Hellical Ribbon	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Axial Deep Grove Ball Bearing	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
V-Belt Pulley Mixer	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Block Press	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
		3	The maintenance officer takes the equipment	10	600
		4	The production floor continues the improvement	10	600
As Moulding	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Vibrator	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Gear Pallet	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Moulding	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Rell Pallet	*Motion*	1	The operator reports the damage to continue WO	8	480
		2	The maintenance officer heads to the production floor where the damage happens	10	600
Total time				667	40020

DISCUSSION OF RESULTS

The results of the data collection and processing in Table 4.10 will be continued to find the root of some waste in QT-10 engine. There are 24 critical components on the QT-10 paving machine during the maintenance; this will be described as follows:

Motion. The displacement activities include the production line machine operator to report the damage to the maintenance department that receives the first Work Order (WO). Repairs are performed when a defective device is found. Preparation of WO is absolutely to be done before the maintenance workers carry out the task. This movement can be minimized by looking at its activity delay code, i.e. trougher idler code 1 and 2, belt code 1 and 2, and so on.

The other motion, non added-value activity, is the time when a maintenance worker takes part in the production team. Then the maintenance worker goes straight to the production line to continue the repair so that the equipment can work again; the improvement activity is coded on trought idler code 4 and 5, belt code 4 and 5, and so on.

The maintenance worker heads to the equipment place at the time of the movement from the production line back to the equipment because the equipment under the production line does not match with the damaged machine. The improvement activity is on block press code 3.

Process. Waste in this classification occurs because workers do not use their knowledge, skills, and abilities optimally. This waste can be explained on trought idler activit, and rell bucket.

Waiting. This type of waste causes machines and operators to be idle and not doing the job effectively. Waste waiting is in the form of waiting for approval of a purchase order by the head of the plant marked into the concrete mixer machine in the spur gear code 4 on authorized waiting activity from BM plant head to sign purchase order so it is classified as workers and machine are not working.

Waste in the form of waiting activities is a part of the production line, done by the maintenance officer and machine operator; this is shown in the concrete mixer machine component of spear gear code 5. This is because the part needed by this maintenance officer is not in the warehouse.

Root Cause Analysis (RCA). The analysis is on causes of waste in QT-10 which will be discussed in this section to find the root cause of the problem by using Root Cause Analysis (RCA). From the results of the identified waste, then we brainstorm with the company to find the root of the problem. The following table shows the root of the problem by using tools of five-why. This is made for each waste.

Waste Motion. Tracing the root cause of waste that occurs based on the five-why method will be presented in the table below:

Tabel 5 – The Root of the Problem *Motion*

Types of problem	*Why* 1	*Why* 2	*Why* 3	*Why* 4	*Why* 5
Waste Motion	Operator movement	From the production line to the maintenance department	The movement takes a relatively long time	Not in one working environment	The absence of an integrated information system and the absence of a toolbox in the production line
		From the maintenance department to the production line			
	Maintenance worker movement	From the production line to the maintenance department			
		From the maintenance department to the equipment			
		From the equipment (warehouse) to the production line			
		From the production line to the maintenance department again			

Table 5 shows that the problem faced by companies associated with maintenance management is waste in the form of excessive movement (waste motion). In general, in the fourth or fifth question, the majority of the root of the problem can already be found. In the above example, the root problem is waste motion as there is no integrated information system that helps to speed up the movement in an effort to perform maintenance activities and there is no placement of equipment on the production line.

Waste Process. Tracing the root problem of waste that occurs based on the five-why method is presented in the table below:

Table 6 – The Root of the Problem *Process*

Types of problem	*Why* 1	*Why* 2	*Why* 3	*Why* 4	*Why* 5
Waste Process	The idler trougher section does not move smoothly	Unpacking idler trougher	Looking for long-lasting damage and deciding on replacement for too long	Handled by a new mechanic	The absence of adequate training for specialized maintenance personnel and lack of team heads provides direction
		Check out the damage of each idler trougher		Mechanics have less expertise in identifying machines	
				It is difficult to decide	
	The hollow belt part	Check the belt on weigher conveyor		Mechanics have less expertise in identifying machines	
				It is difficult to decide	
	The crump bucket section	Check the rell bucket on bucket conveyor		Mechanics have less expertise in identifying machines	
				It is difficult to decide	

Table 6 shows that the problem faced by companies associated with maintenance management is waste in the process of identifying the old damage and the long time in deciding the part that must be replaced. In the above example, the root problem is inadequate skill of the maintenance workers, so the identification process takes longer time and the production team head gives less direction to the new mechanics about the components that should be replaced making it hard forthe maintenance worker to make a final decision. This is because of not enough training to improve the skill of maintenance operators and the lack of guidance from the team heads.

Waste Waiting. Tracing the root cause of waste that occurs based on the five-why method is presented in the table below:

Table 7 – The Root of the Problem *Waiting Process*

Types of Problem	*Why* 1	*Why* 2	*Why* 3	*Why* 4	*Why* 5
Waste Waiting	The request process is authorized by the head of the team	Waiting for the availability of an authorized work order from the plant head	The head of the plant is not at work	Checking and ensuring raw material inventory	No special supervision to manipulate production lines
	Waiting for the part to be available	Spur gear mixer not provided	Part is too expensive	Finance provided for inventory by a minimum center	There is no supply for large components

Table 7 shows that the problem faced by companies associated with maintenance management is waste in the form of waiting. In the above example, the root of the problem is the unavailability of the plant head so the authorized work order must be delayed waiting for the plant head to present. In addition, the worn out spur gear part of the concrete mixer part cannot be repaired—it must be replaced with a new one. It is not available in the warehouse, and then a purchase must be made. As there is no supervisor on the production line and the absence of expensive components, when damaged happens, the purchase takes too much time.

Recommendations for Improvement. We make some recommendations as to improve the company's performance, especially in the field of maintenance. Proposed improvements are given based to the results of RCA (Root Cause Analysis).

To reduce the excessive movement along the flow of maintenance activities, the company must create an Information System of Maintenance: A brainstorming with the maintenance management must be done as to create an integrated management system. The objective is to shorten the time of movement by providing the necessary equipment.

The information system requires:

- Operating system Windows 7, full software (standard program), software;
- Procurement of computers in production;
- LAN cable ± 300 meters in the production line - shift head and ± 1200 meters in the team head to head office of BM and wireless telephone;
- Toolbox 56 x 27.8 x 27 centimeters.

The recommended improvements to reduce the waste process in the flow of maintenance activities are training and more guidance from the head of the team.

The training is carried out by experts in maintenance as to channel knowledge from the experts to the newly working mechanics. Training may take time during the machinery one-day off as to not interfere with the course of production.

Employees will understand about the belt weigher conveyor and mixer concrete in the training. Giving annual rewards to the head of the team who always actively guide and direct employees on the production line during maintenance activities is also a good way to improve performance.

The recommended improvements to reduce the waste waiting in the flow of maintenance activities are as follows.

It is better that the head of the plant has a supervisor to bolster the working group, to control and evaluate the production line, and to provide information on production conditions. If a supervisor is available, then the maintenance requiring a plant head signature, such as for purchase order, can be represented by the supervisor. This may relate to problems such as lack of sparetpart spur gear mixer. With a regular checking schedule, replacement may not wait for too long, since at least one spare part is provided.

The above recommendations will continue in the analysis of waste improvements. In the reduction of waste especially motion, process, and waiting, the total overall repair activity is classified as waste by 30%.

Maintenance Lead Time Reduction Analysis. With the recommendations proposed, now we can calculate the total lead time from every maintenance process. The following table identifies the time of damage and maintenance activities:

Table 8 – The Data of Damaged Machinery (1 year)

No	Machine name	Damage time (Minutes)
1	*Belt Weigher Conveyor*	1055
2	*Bucket Conveyor*	400
3	*Mixer Concrete*	655
4	*Host Mechine*	590
	Total	2700

It has gone through the Value Stream Maintenance Mapping (VSMM). Table 8 illustrates the total time on waste identified as follows: Waste motion by 532 minutes; Waste process by 45 minutes; Waste waiting by 90 minutes.

Thus, the total amount of waste is 667 minutes or 40020 seconds. We then look for the root of the problem using RCA. Once the root of the problem is found, then the recommendations for improvement are described. The total reduction of lead-time maintenance is 30/100 x 40020 = 12006 seconds (200.1 minutes).

Then the result of the lead-time improvement activity after the proposed recommendations for improvement with 30% of each waste is equal to:

{(2700 minutes x 60sec}} - 12006 seconds} = 162000-12006 = 149994 seconds

An Analysis of Equipment Effectiveness Improvement. By applying the recommended improvements to reduce the existing waste in each maintenance process, then the benefit is an increase in the effectiveness of equipment or factory machinery. Here is the calculation of the equipment effectiveness (E):

Cycle Time = 1.70 seconds per paving

Working Hour = 262800 minutes/year

Break Time = 37440 minutes/year

Breakdown Time (unplanned)

From the calculation of waste to damaged time during one-year interval from January to December 2016 through RCA equals to 149994 seconds/year or 2499.9 minutes/year.

Effective Time (Te):

The total working hour for one year is 262800 minutes.

Productive Time (To):

It is the effective time reducing breakdown for one year which equals to 262800 minutes/year or 2499.9 minutes/year = 260300.1 minutes/year.

Actual Time:

It is the actual time the machine is really doing the work. The formula is as follows:

Actual Time = (Productive Time - Break Time)

= (260300.1 minutes/year - 37440 minutes/year)

= 222860.1 minutes/year.

From the results of points 1 to 7 above is a parameter that will be included in the calculation of the effectiveness of the machine type QT-10 as below:

Calculating Total Products Manufactured (N):

N = (Actual Time : Cycle Time) = (222860.1 x 60) : 1.70 seconds/product

= (13371606 seconds/year : 1.70 seconds/product)

= 7865650.5882 product/year = 7865651 products/year

Maximum Number of Products (Nmax):

Nmax = Te: Cycle Time = (262800 x 60) : 1.70 seconds/product

= 1576800 seconds/year: 1.70 seconds/product

= 9275294.11 products/year = 9275295 products/year

Number of Qualified Products (NQ):

NQ = N - Product defect= 7865651 products/year - 59480 products/year

= 7806171 products/year

The above results are included in the model calculation below:

Availability (A)= To : Te = 260300.1 minutes/year : 262800 minutes/year = 0.9904
Performance Effeciency (R) = N : Nmax = 7865651 products/year : 9275295 products/year = 0.8480
Quality Rate (Y) = NQ : N = 7806171 products/year : 7865651 products/year = 0.9924
Eqipment Effectivenees (E) = A x R x Y = 0.9904 x 0.8480 x 0.9924 = 0.8334 = 83.34%

From the calculation above, the effectiveness of the equipment after the waste reduction of 30% of the overall maintenance process in QT-10 paving is 83.21% before the improvement to 83.34% after improvement. Then the increase after the recommended improvements is 0.13%.

From the calculation of activity time using RCA, the obtained time delay includes waste (motion, process, and waiting). Waste is traced using Value Stream Maintenance Mapping. For the each identified waste is reduced by 30%. For RCA (Root Cause Analysis) results, 30% of the maintenance activity, identified on Table 4.17, equals to 40020 seconds (667 minutes), and reduces to 28014 seconds (466.9 minutes) after passing RCA.

From the results of the maintenance process on QT-10, waste in the activity of QT-10 paving machine is 532 minutes for waste motion by, 45 minutes for waste process, and 90 minutes for waste waiting. Recommendations given are providing an integrated information system, training, rewards, and having a production line supervisor. Before the recommendation, the delay is 2700 minutes (162000 seconds) and after recommendation it reduces to 2499.9 minutes (149994 seconds).

CONCLUSION AND SUGGESTIONS

Based on the results and data analysis, it can be concluded that:

Waste in the maintenance activity of QT-10 type paving machine in PT Varia Usaha Beton Gresik are: Waste motion by 532 minutes; Waste process by 45 minutes; Waste waiting by 90 minutes.

Some improvements to be made: Waste motion by providing maintenance information system; Waste process by conducting training involving the experts in maintenance and giving reward to employees; Waste waiting must be located in a production line and spare part spur gear mixers must be made available at least one part to reduce waiting time.

From the results of the discussion and conclusions described above, suggestions can now be given:

PT Varia Usaha Beton Gresik must understand the existing waste in the maintenance activities to increase production and effectiveness of the existing equipment.

Waste can be reduced by making a maintenance information system, giving job training to new mechanic, and giving reward for team heads who are actively involved in guiding employees in the production line. For the control of the entire production activity, all activities must be scheduled. Components and spare parts must be made available as to reduce the engine output every minute.

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