ITB Graduate School Conference (IGSC) ISSN: 2963-718X
December 21, 2021

# Waste Reduction in Manufacturing Companies for Continuous Quality Improvement Using Waste Assessment Model (WAM) And Deming Cycle Method (PDCA)

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**Abstract.** This paper explains what wastes occur in the work environment, namely overproduction, waiting, transportation, overprocessing, motion and defect. The goal of this study is how to identify critical waste and identify the source of waste that occurs in the work environment and then reduce the waste by WAM and PDCA methods. The method used to identify waste is the waste assessment model (WAM). The waste assessment model consists of 2 stages, namely waste relationship matrix (WRM) and waste assessment questionnaire (WAQ). From the results of waste assessment models will be obtained the most dominant waste that occurs in the work environment so that it can be prioritized to be completed compared to other arising waste. Then the most dominant waste is improved by the Deming cycle (PDCA) method consisting of 8 steps. The results of this study obtained critical waste from 7 waste, namely waste defects and the source of the cause of waste defects is the frequency of damage that occurs in the dewatering area. The company lost the opportunity to process raw materials as much as 46,395 kg within 6 months and within the quarter waste has been eliminated to maximize the production process.

***Keywords****: continous improvement; deming cycle; waste assessment model; reduce waste;*

## 1 Introduction

PT ABC is a manufacturing company that produces tapioca flour. Tapioca flour is obtained by processing cassava with a certain rate of starch and yield. The processing process also goes through several stages, starting from the input process RM, washing, milling and rasping, extracting, refining, dewatering, drying, and packaging. In the process of processing, it turns out that there is often waste (waste) on the production line.

Waste is any type of work activity that does not add value to the process of converting inputs into outputs. The waste consists of two forms, namely form 1 and form 2. Form 1 is a waste that has no added value but this activity is inevitable. While form 2 is waste that does not add value and must be eliminated because the existence of waste is what can reduce the quality of a production process proposed by Gaspersz and Fontana in [1]. Therefore, lean methods need to be used to reduce waste that occurs in the production line. Waste identified in lean includes inventory, transportation, waiting, overproduction, overprocessing, rework/rejection, and unneeded movements proposed by Bhamu and Sangwan in [2]. Here is a table of waste data that occurs in the production line of PT ABC:

**Table 1** Leadtime data on production for the period January - June 2021.

| Process | Leadtime (minute) | Percentage |
|---|---|---|
| Purifiying | 1055 | 14,48% |
| Processing | 5960 | 81,78 % |
| Drying | 273 | 3,75 % |
| Total | 7288 | 100 % |

Based on the waste data in the company to be studied and some existing literature, the application of identification of 7 wastes in the company to be studied did not apply problem identification based on all aspects of 7 waste so that the target of improvement is not appropriate/main then the researcher proposes to do research related to the development of PDCA methods by determining critical waste points with the Waste Assessment Model (WAM) method first then doing the PDCA method. in preparing the completion or repair of critical waste. WAM is used to check and resolve which wastes should be prioritized in the implementation of the improvements proposed by Ali and Fahad in [3]. The WAM stage consists of 2 stages, namely waste assessment matrix and waste assessment questionnaire. While the PDCA method is used to reduce critical waste that occurs from WAM. The PDCA method is a continuous improvement model developed by W. Edward Deming that consists of 8 stages but broadly speaking the stages are the plan, do, check, and action proposed by Gaspersz in [4].

## 2 Mapping The Relationship Between Waste and Waste Assessment Matrix

This stage is done to find out the relationship between waste with the explanation of the relationship presented in the appendix. Calculation of the interrelationship between waste is done by open and closed interviews through questionnaires to corporate experts, namely dept head of Production, Warehouse, Engineering, Quality control and continuous improvement.

Toyota's production system (TPS) aims to increase organizational productivity and reduce costs by eliminating waste. There are 7 wastes proposed by Bhalaji, et al in [5] :

1. Overproduction
2. Waiting
3. Transportation
4. Overprocessing
5. Inventory
6. Motion
7. Defect

After interviewing and filling out a questionnaire based on aspects of Rawabdeh's question, the score results from the level of the interrelationship between wastes will then be converted into the following values proposed by Rawabdeh in [6]. Here is a table of relationships formed between waste whether it is waste that affects "from" or waste that is influenced "to":

**Table 2** Relationship Mapping 7 Waste.

| No | Waste Relationship | Questions 1 | 2 | 3 | 4 | 5 | 6 | Total | Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 1 | W_O | 2 | 1 | 2 | 0 | 2 | 4 | 11 | I |
| 2 | W_I | 2 | 1 | 4 | 1 | 2 | 2 | 12 | I |
| 3 | O_T | 2 | 1 | 4 | 1 | 1 | 2 | 11 | I |
| 4 | O_I | 4 | 2 | 4 | 0 | 2 | 4 | 16 | E |
| 5 | I_D | 4 | 2 | 4 | 2 | 4 | 4 | 20 | A |
| 6 | I_O | 4 | 0 | 4 | 2 | 2 | 4 | 16 | E |
| 7 | I_W | 2 | 1 | 2 | 1 | 4 | 2 | 12 | I |
| 8 | D_W | 4 | 2 | 2 | 1 | 2 | 2 | 13 | E |
| 9 | D_P | 4 | 2 | 4 | 2 | 4 | 4 | 20 | A |
| 10 | D_M | 2 | 1 | 2 | 0 | 2 | 2 | 9 | I |
| 11 | D_O | 4 | 2 | 4 | 2 | 4 | 4 | 20 | A |
| 12 | P_D | 4 | 2 | 4 | 2 | 4 | 4 | 20 | A |
| 13 | M_T | 4 | 1 | 0 | 1 | 1 | 2 | 9 | I |
| 14 | T_M | 4 | 1 | 2 | 1 | 1 | 4 | 13 | E |

After obtaining the weight and category of relationships between existing waste, the next stage moves the category of relationships between wastes into the waste relationship matrix proposed by Rawabdeh in [6]. Here is a table of waste relationship matrices formed:

**Table 3** Waste Relationship Matrix.

| F/T | O | I | D | M | T | P | W |
|---|---|---|---|---|---|---|---|
| O | A | E | X | X | I | X | X |
| I | E | A | A | X | X | X | I |
| D | A | X | A | I | X | A | E |
| M | X | X | X | A | I | X | X |
| T | X | X | X | E | A | X | X |
| P | X | X | A | X | X | A | X |
| W | I | I | X | X | X | X | A |

Then the table above is converted to the following values A = 10, E = 8, I = 6, O = 4, U = 2 and X = 0 proposed by Rawabdeh in [6] so that the following results are obtained :

**Table 4** Conversion WRM.

| F/T | O | I | D | M | T | P | W | Total | % |
|---|---|---|---|---|---|---|---|---|---|
| O | 10 | 8 | 0 | 0 | 6 | 0 | 0 | 24 | 13,48 |
| I | 8 | 10 | 10 | 0 | 0 | 0 | 6 | 34 | 19,10 |
| D | 10 | 0 | 10 | 6 | 0 | 10 | 8 | 44 | 24,72 |
| M | 0 | 0 | 0 | 10 | 6 | 0 | 0 | 16 | 8,99 |
| T | 0 | 0 | 0 | 8 | 10 | 0 | 0 | 18 | 10,11 |
| P | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 20 | 11,24 |
| W | 6 | 6 | 0 | 0 | 0 | 0 | 10 | 22 | 12,36 |
| Total | 34 | 24 | 30 | 24 | 22 | 20 | 24 | 178 | 100 |

Based on the table above it is known that waste that has a considerable influence on other waste "from" is a defect with a percentage of 24.72%. And the waste that occurs caused by other waste "to" is waste overproduction with a percentage of 19.10%.

## 3 Determine Critical Waste with Waste Assessment Questionare

Waste assessment questionare is a questionnaire that contains questions to recognize the source of waste that occurs in the work environment. The table below shows the weight of the interrelationship between question type waste in waste assessment questionare, this weight is obtained from moving the score in the table above by the type of question available. Here is a table of calculations from critical waste:

**Table 5** Critical Waste Calculation.

| | **O** | **I** | **D** | **M** | **T** | **P** | **W** |
|---|---|---|---|---|---|---|---|
| A | 0,88 | 0,89 | 0,84 | 0,85 | 0,86 | 0,82 | 0,81 |
| B | 257 | 257 | 417 | 121 | 125 | 126 | 167 |
| C | 226 | 229 | 351 | 103 | 108 | 103 | 135 |
| D | 18 | 18,28 | 27,94 | 8,20 | 8,59 | 8,21 | 10,77 |
| E | 3 | 2 | 1 | 7 | 6 | 5 | 4 |

Information :

A = Score (Yj)

B = Pj Factor

C = Final result (Y Final)

D = Percent final result

E = Rating

$$Yj = \frac{sj}{Sj} \text{ x } \frac{fj}{Fj} \quad (1)$$

Where :

sj = the total of the weight of the questionnaire results

fj = the frequency of questionnaire results that are not 0

Sj = the total initial weight of waste

Fj = the initial frequency of waste that is not 0

The Pj factor is obtained by multiplying the percentage (%) of "from" by the "to" in the table above. The final result (Y Final) is obtained by multiplying Yj by Pj factor. While the final result is obtained by dividing the Final Y of each waste by the total of Y Final.

From the table above it can be concluded that the most dominant waste or critical waste that occurs in the work environment is a waste defect with a percentage of 27.94% then the second-largest critical waste is waste inventory with a percentage of 18.28%.

## 4 Reduce Critical Waste with Deming Cycle (PDCA) Method

The first step of kaizen is to implement the PDCA cycle (plan, do, check, action) as a means to ensure the survival of the kaizen. It is useful in realizing policies to maintain and improve standards or quality. The concept of the PDCA cycle was first introduced by Walter Shewhart in the 1930s called the "Shewhart Cycle". PDCA stands for English from plan, do, check, action (plan, work, check, follow-up), is a four-step interactive problem-solving process commonly used in quality control. Subsequently, this concept was developed by Dr. Walter Edwards Deming who came to be known as "The Deming Wheel" proposed by Nugroho, et al in [7].

Deming cycle is a tool designed for continuous repair. In some cases, this method is used for further improvement and control on the security of explosive prequels proposed by Zedadra, et al in [8]. Continuous process improvement is a key concept of total quality management (TQM) proposed by Roriz, et al in [9].

**Step 1**. Define problems and define repair themes

A problem is defined as a gap between the present situation (actual performance) and the desired performance target. The theme of improvement should be directly related to the PQCSDME performance problems (productivity, quality, cost, safety and service, delivery, morale, environment) faced by the respective company work environment proposed by Gaspersz in [4].

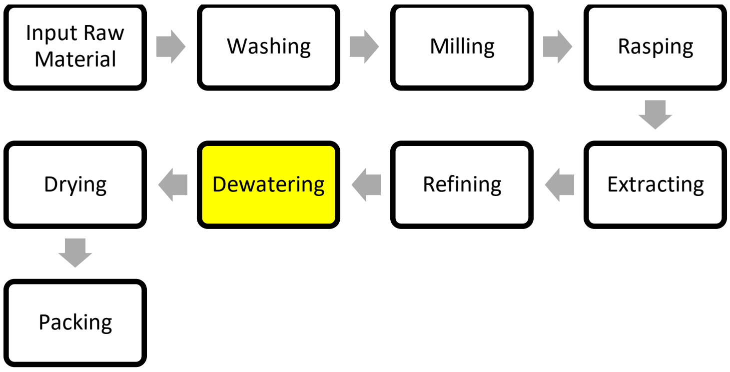


**Figure 1** The company's production process.

From the description of the process above, it is known that the area that will be repaired is the dewatering area. This area is the area of the first drying process, liquid starch is separated by water using a vacuum drum so that it becomes a powder form. Here is the SBL data table in the production area from January to June 2021:

**Table 6** Six Big Loses Production Area Jan - Jun 2021.

| SBL | Month | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | |
| Late start & Early stop | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Idling & Minor stop | 127 | 415 | 1057 | 486 | 20 | 464 | 2569 |
| Technical Breakdown | 1188 | 1241 | 1069 | 4868 | 324 | 1150 | 9840 |
| Set up & Adjusment | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Reduceed Speed | 2601 | 2075 | 286 | 23 | 174 | 253 | 5412 |
| Deffect & Rework | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

The table above shows the time of the six big losses is the most technical breakdown of 9,840 minutes. Below is a table of SBL technical breakdown data that occurred in the production area from January to June 2021:

**Table 7** Six Big Loses Technical Breakdown in production area Januari-Juni 2021.

| SBL Technical Breakdown | Month | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | Mei | Jun | |
| Mechanical | 588 | 619 | 860 | 4763 | 134 | 1080 | 8044 |
| Utility | 480 | 394 | 103 | 37 | 190 | 0 | 1204 |
| Electrical | 120 | 228 | 106 | 68 | 0 | 70 | 592 |
| Total | | | | | | | 9840 |

The table above shows the most SBL Technical breakdown, which is mechanical damage of 8,044 minutes or 82% so that the problem is prioritized to be solved.

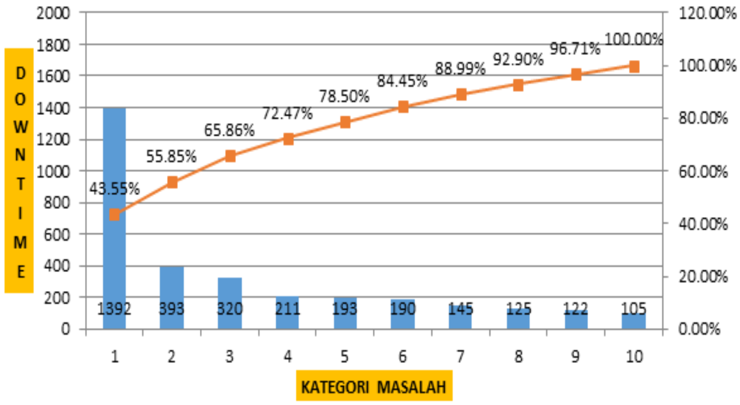


**Figure 2** Grafik mechanical damage in Jan-Jun 2021.

Based on the graph and data above, the theme of improvement is to reduce mechanical downtime due to damage to a broken vacuum agitator in the dewatering area.

**Step 2**. Looking for all possible causes

At this stage, identification of all causes may result in the problem that has been identified in step 1. Identification is done by brainstorming with the 4M+1E method. From this stage obtained the possibility of the cause of the problem of damage to the broken agitator. Here is a table of damage problems that occur:

**Table 8** Brainstorming Causes Problems.

| No | Faktor | Problem |
|---|---|---|
| 1 | Materials | Pneumatic arm material is less thick so it is easy to break |
| 2 | Machines | Pneumatic arm is easily broken because it connects with welding only and the grip of the bolt to the nut is too short |
| | | Pneumatic cylinder mount is not suitable so that the sying and shaft cylinder are not symmetrical |
| 3 | Methods | Vacuum thring methods are less precise causing the load of the agitator to become heavy |
| 4 | Man | Operator has not run the stages of vacuum platform according to LIK |
| 5 | Environment | Don't Exist |

**Step 3**. Analyze the root cause of the problem

The next step is to analyze the root cause of the problem that arises. Root cause analysis (RCA) analyzes a system to determine and identify the cause of a problem. The tool used is a why-why diagram or fishbone diagram so that the appropriate action on the root cause of the problem found eliminates the problem.

Fishbone diagram is one of the methods/tools in improving quality. Often these diagrams are also called Cause-and-effect diagrams. Its inventor was a Japanese scientist in the 60s. Dr. Kaoru Ishikawa is a scientist born in 1915 in Tokyo Japan who is also an alumnus of chemistry at the University of Tokyo. It is often called the Ishikawa diagram. The basic function of the Fishbone/Cause and Effects/Ishikawa diagram is to identify and organize the possible causes of a particular effect and then separate the root cause proposed by Nugroho, et al in [7].

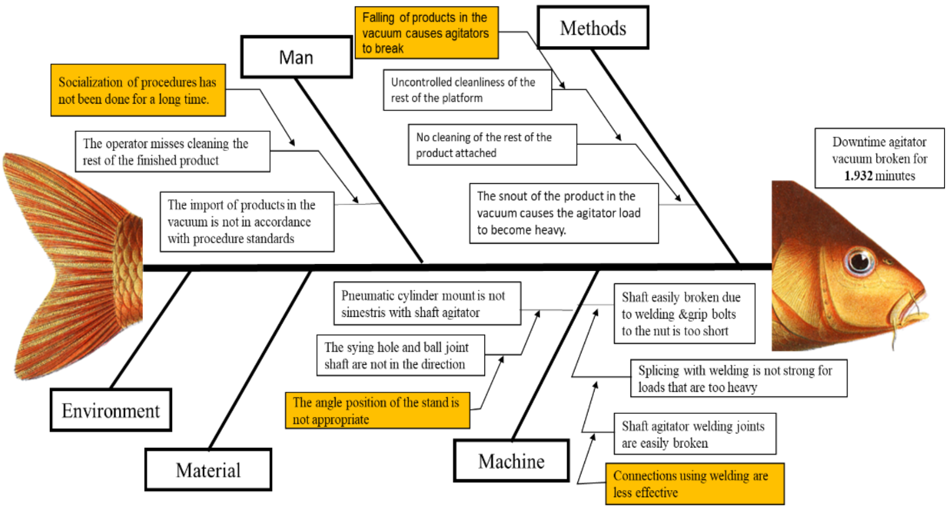


**Figure 3** Fishbone diagram.

**Step 4**. Planning improvement action

At this stage, the determination of the planning steps of improvement action against the root cause of the problem that arises. The method used for this planning is the 5W+2H method.
From this stage, an improvement plan is obtained.
1. The operator slices the product in the vacuum if the product is wet.
2. Replace the agitator shaft design
3. Replace the symmetrical pneumatic stand between the stance hole and shaft agitator
4. Re-coaching about work instructions to the operator.

**Step 5**. Implementation the improvement

This stage is carried out with the implementation of the improvement plan that has been made before. The implementation of these corrective actions requires the commitment of management and employees and total participation to jointly eliminate the root causes of the problems that arise. During the implementation phase, data recording is also required in case of irregularities during the implementation process.

**Step 6**. Evaluation of improvement results

At this stage, an evaluation of the improvements that have been made in 4-6 months. Be it from the cost savings generated, the impact arising from repairs, and so on. From the results of improvements that have been obtained :

1. Shaft agitator with stainless steel material so that it is not easily broken.
2. The symmetrical pneumatic stand between the stance hole and the shaft agitator.

Saving costs obtained from the results of this repair amounted to Rp. 2,621,299,524,-/ Year.

**Step 7**. Standardize repair solutions

After the repair is considered successful or does not cause any impact or damage that is expected then the results of repairs are made standard so that the results of repairs made are standardized for future use. Standardization is done by standardizing the work instructions from cleaning after breaking the vacuum.

**Step 8**. Create a final report and determine the next improvement plan

The last stage is done making a report about the improvements that have been made or recording the progress of improvements. Then seek or determine the next improvement plan so that the improvement is continuous or sustainable.

From the data found in the field, the next problem is determined which is the next fix, namely the occurrence of waste in the process area 2 as a result of the number of wasted starch loses in the waste and waste tub.

## 5 Conclusion

The results of the study obtained that the most dominant or critical waste of the five departments is a waste defect. After being identified the source of the cause of waste defects comes from the high downtime due to defects/damage to the engine in the dewatering area, namely agitator defects that cause lead time that can hamper the course of the production process. Eliminating or decreasing waste that occurs in the work environment is obtained by using the Waste Assessment Model (WAM) and using the Deming cycle (PDCA) to eliminate/decrease the waste that arises. Both of these methods are very good to use and develop PT ABC because the identification of waste that occurs in the work environment is more thorough or based on 7 waste and makes it easier for employees to identify the source of waste and prioritize improvements to the most dominant waste occurs.

From the research that has been done on PT ABC has lost the opportunity to process raw materials (RM) as much as 46,395 kg within 6 months. But after improvements in the quarter of the semester (3 months) waste has been eliminated so that the production process can be maximized.

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