Improving Overall Equipment Effectiveness Using CPM and MOST: A Case Study of an Indonesian Pharmaceutical Company

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Abstract. This paper discusses the results of a research conducted on the production process of an Indonesian pharmaceutical company. The company is experiencing low performance in the Overall Equipment Effectiveness (OEE) metric. The OEE of the company machines are below world class standard. The machine that has the lowest OEE is the filler machine. Through observation and analysis, it is found that the cleaning process of the filler machine consumes significant amount of time. The long duration of the cleaning process happens because there is no structured division of jobs between cleaning operators, differences in operators' ability, and operators' inability in utilizing available cleaning equipment. The company needs to improve the cleaning process. Therefore, Critical Path Method (CPM) analysis is conducted to find out what activities are critical in order to shorten and simplify the cleaning process in the division of tasks. Afterwards, The Maynard Operation and Sequence Technique (MOST) method is used to reduce ineffective movement and specify the cleaning process standard time. From CPM and MOST, it is obtained the shortest time of the cleaning process is 1 hour 28 minutes and the standard time is 1 hour 38.826 minutes.

1. Introduction

Intense competition in the business world encourages every company to improve the quality in terms of products / services, performance of work and the company itself. Companies must be able to make continues improvements to develop their business. Particularly in the pharmaceutical field which is related to health. All kinds of drugs are produced should undergo any sterile process to produce good medicine.

Company X (the real name of the company is withheld due to confidentiality reasons) is a manufacturing company that produces pharmaceutical products, such as herbal remedies, supplements, and pharmaceutical drugs. In the production process, each machine affects the Overall Equipment Effectiveness (OEE) metric. Company X is facing a problem related to the machines. The problem is the availability rate of the machines.

World-class standard of OEE as stated by Frost and Sullivan is 85% composed of three factors that are Availability (90%), Performance (95%), and Quality (99%) [1]. The OEE metric achieved by Company X was 60% in 2015 for the area of production of liquid (fluid). Company X decided that the target for OEE metric in 2016 is 70%.

The purpose of this research is to increase OEE through improving availability, as one of OEE’s factor, in order to achieve the OEE metric target for 2016. The current availability rate is below 70%
while the performance rate and quality rate is already above 90%. To increase availability, this study uses CPM and MOST. MOST has a vital role in the efforts to reduce or eliminate idle and/or down time, improve the working methods, standardize the time as well as enhance the overall capacity planning [2]. Researches on OEE Improvement by using MOST is not widespread. As far as the authors know, there are only few other researches that use MOST to improve OEE, especially in the pharmaceutical setting. Therefore, the results of this research can be used for future reference for other researches.

This study starts with the observation of production process on each machine to get the current OEE. Then, determine the machine to be focused and causation that may occur. The next step is to repair the flow of activities and division of tasks by using CPM. The final result of the improvement is in the form of standard time as the latest time limit by MOST and allowance.

2. Literature Review

2.1. Overall Equipment Efficiency
To determine the effectiveness of the equipment there is a calculation method that can be used is Overall Equipment Effectiveness [3]. Overall Equipment Effectiveness (OEE) is generally used as an indicator of the performance of the use of equipment. OEE measurement is important to show which areas have a bottleneck in the production line. Moreover, it can be used as a measuring tool to evaluate and improve the proper way to increase the productivity of machinery/equipment. The value of the OEE itself is obtained from the multiplication of three main factors, namely availability rate, performance rate and quality rate, as follows [4]:

\[
\text{Availability rate} = \frac{\text{Required Availability} - \text{downtime}}{\text{Required Availability}} \times 100% \\
\text{Performance rate} = \frac{\text{Output} \times \text{Optimal cycle time}}{\text{Operating time}} \times 100% \\
\text{Quality rate} = \frac{\text{Processed input} - \text{Quality defects}}{\text{Production input}} \times 100% \\
\text{OEE} = \text{Availability Rate} \times \text{Performance Rate} \times \text{Quality Rate}
\]

Availability ratio measures the overall time when the system is not operating due to the damage to the equipment, production preparation and adjustment. Performance ratio is measured as the ratio of the actual operating speed of the equipment with ideal speed based on design capacity. Quality ratio focused on how much quality loss in the form of defective products which occurred in connection with the equipment.

2.2. Improved Quality Technique

2.2.1. Pareto Diagram
Problem areas can be defined by the technique developed by the economist Vilfredo Pareto to describe the concentration of wealth. In the analysis of Pareto, the interesting part is to identify and measure on a common scale that was then ordered in descending order, as the cumulative distribution. This technique is commonly called the 80-20 rule [5].

2.2.2. Cause-Effect Diagram
This method defines the occurrence of events which are usually undesirable or problem, namely the effect, as "fish head" and then identify the factors, which is the cause, as "fish bone" [5]. The main
cause is usually divided into five or six major categories, namely humans, machines, methods, materials, environments, and administration, each subdivided into several causes.

2.3. Critical Path Method
The critical path is a series of activities of a project that cannot be delayed the implementation time and show relationships that are interrelated to one another [6]. The more critical path exists in a project, the more activities that should be monitored intensively. This strategy is also frequently used in shortening project duration [7]. In general, network diagram can be drawn using the activity on node (AON) and activity on arrow (AOA) as can be seen in Figure 1.

2.3.1. Activity on Node (AON)
The activities are represented by points / nodes. The arrows simply explain the relationship of dependence between activities.

2.3.2. Activity on Arrow (AOA)
The activities are represented by arrows connecting the two circles that representing two events. The tail of the arrow is the beginning of the activity, while its end signaling as the end.

| AON | AOA |
|-----|-----|
| ![Diagram of AON and AOA](Image)

**Figure 1.** Comparison of AON and AOA

The process used to determine the time schedule for each activity is a two-pass consisting of a forward pass (ES and EF) and the backward pass (LS and LF), as can be seen in Figure 2. Forward pass and backward pass using a notation to indicate the schedules of activity on the network project clearly as follows [6]:

- Earliest Start (ES): the earliest time an activity can begin by assuming all its predecessors have been completed.

  \[ \text{ES} = \text{Max \{EF all immediate predecessors\}} \]  

- Earliest finish (EF): The earliest finish time for an activity amount of the earliest start time (ES) and time of the activity itself.

  \[ \text{EF} = \text{ES} + \text{Time Activities} \]  

- Latest Finish (LF): the last time an activity can be completed so as not to delay the completion of the entire project.

  \[ \text{LF} = \text{Min \{LS from all activities that directly follow\}} \]  

- Latest Start (LS): Last time an activity can be initiated so as not to delay the completion of the entire project.

  \[ \text{LS} = \text{LF} - \text{Time Activities} \]
Slack is the time owned by an activity to be postponed without causing delays in the project implementation as a whole. Activities with slack = 0 is referred to as a critical activity and are on the critical path. Mathematically it can be written as follows:

\[ \text{Slack} = LS - ES \text{ or } LF - EF \] (9)

2.4. Motion and Time Study

Motion and time study aim to eliminate unnecessary work and design most effective methods and procedures while providing methods of measuring work to determine a performance index for an individual or group of workers, department or entire plant. Motion and time study consists of four parts and two parts [8]:

- Motion study or work methods design: to find the preferred method of conducting work.
- Time study or work measurement: to obtain the standard time to perform a specific task.

2.5. Maynard Operation and Sequence Technique

Maynard Operation and Sequence Time (MOST) is a motion time system that is mostly used in industrial setting to set the standard time of workers’ tasks [2]. This technique is based on the order of sub activities or movements. MOST quantifies work content by evaluating the movement of objects [9]. Each type of movement has different sequence. Therefore it is necessary to separate the model sequence of events in this method. Table 1 illustrates the sequence of movements in the MOST [5]:

| Activity | General Move | Controlled Move | Tool Use |
|----------|--------------|-----------------|----------|
| Sequence Model | ABGABPA | ABGMXIA | ABGABP*ABPA |
| Parameters | | | |
| A-Action distance; B-Body Motion; G-Gain Control; P-Place | M-Move Controlled; X-Process Time; I-Alignment | *F-Fasten; L-Loosen; C-Cut; S-Surface treat; M-Measure; R-Record; T-Think |

On the use of MOST method of measuring standard time, there is little difference that is not looking for a normal time needed first. To get the standard time, we can simply by adding the allowance to the normal time has been obtained [10].

\[ \text{Standard time} = \text{normal time} \times \left(100\% \div \text{normal time} \times \text{allowance}\right) \] (10)

Time units in the MOST technique are based on Time Measurement Unit (TMU). The following is the conversion value between normal time and TMU [2]:

| Activity | General Move | Controlled Move | Tool Use |
|----------|--------------|-----------------|----------|
| Sequence Model | ABGABPA | ABGMXIA | ABGABP*ABPA |
| Parameters | | | |
| A-Action distance; B-Body Motion; G-Gain Control; P-Place | M-Move Controlled; X-Process Time; I-Alignment | *F-Fasten; L-Loosen; C-Cut; S-Surface treat; M-Measure; R-Record; T-Think |
• 1 hour = 100,000 TMU
• 1 minute = 1,667 TMU
• 1 second = 27.8 TMU
• 1 TMU = 0.00001 hour = 0.0006 minute = 0.036 second

MOST assists in process standardization by evaluating the standard time per cycle and ignores unnecessary activities [11]. It is used to identify and analyze value added and non-value added activities [12]. By applying MOST, resources can be deployed efficiently [13].

2.6. Allowance
Allowance granted to three things: the personal needs, relieve fatigue and barriers that cannot be avoided [10].

3. Methodology
The research process consists of several steps. The first step is to do observations on the company and see the problem.

Observation is made on the production of liquid medicine. Based on observations, existing problem is Overall Equipment Effectiveness percentage is still low on a particular machine. Therefore the objective to be achieved is to increase the value of OEE with improvements on the cause of the problems.

Data that can be collected in this study are primary data and secondary data. Primary data were successfully observed directly are the cleaning work processes, the element of work each process, and the time of each work process. While secondary data obtained from the company are the output of production and log sheet each production.

In addition to see the percentage of OEE, the result of OEE is also to see the bottleneck area. From that result, it will be easier to evaluate and improve the existing machines.

Based on data collected, Pareto Diagram analysis is conducted to define which process takes the longest time. Then, Cause-Effect Diagram is developed to analyze the causes that make that certain process consume the longest time. Afterwards, Critical Path Method is utilized to determine the division of tasks. Maynard Operation and Sequence Technique are conducted to define the normal time of the process.

4. Results and Discussions

4.1. Overall Equipment Effectiveness
To see a machine can be said to be effective in a company, any company applying a calculation method that is Overall Equipment Effectiveness. This method uses the parameters of time and quantity which results in a percentage.

Table 2. OEE Comparisons between Filler and Mixer Machine
Based on the data recapitulated the filler machine and the mixer machine (Table 2), it can be seen that the effectiveness of the filler machine has decreased in each month, while the mixer machine has increased. So the filler machine is the one that needs to be improved.

4.2. Pareto Diagram and Cause-Effect Diagram
Of the three OEE factors, the percentage was lowest for the availability factor of the machine before using it with the longest time held when the machine stopped with 26.5% and the cleaning process with 36.7%. We can see in the following Pareto diagram (Figure 3) for each data losses in the machine filler which occurred in June 2015-October 2015. Incident when the machine stops can be tolerated because there is a lot of activity in which operators use a break or tidying up the room after production.

![Pareto Chart of Filler Machine](image)

**Figure 3.** Pareto Chart of Filler Machine

To determine the factors influencing the decline in OEE and determine the causes and consequences of the length of the cleaning process, it can be used cause-effect diagram (Figure 4).

![Cause-Effect Diagram](image)

**Figure 4.** Cause-Effect Diagram

Based on the diagram, there are 6 main causes in the lengthy process of cleaning that is personnel, material, measurement, machines, methods, and also the environment. The causes are the ability/skill different operators, lack of operator which also interfere in the process of shifting work scheduling or operator. The different types of cleaning (major/minor) also affect the long or fast cleaning. Previous average time spent on cleaning is 2.5 hours for the major types. In addition to the Standard Operating Procedure (SOP) that does not explain the distribution of the cleaning process for the operator also
makes the process of being unstructured. The cause is not actually in the calculation of OEE can also occur because each room there is no clock or a stopwatch to see the exact time so that the operator will write time according to its own estimates. Then the problem of cleaning the room for those far from the machine room and less supportive tool for cleaning makes the cleaning process becomes longer do.

4.3. Critical Path Method

Critical Path Method (CPM) is applied to determine the division of tasks that can be carried by two operators. Designed a structured process based on the activities of the predecessor that had to be done before the next activity.

Table 3. Predecessor Activities on Cleaning Process

| Activity                                      | Time (Minutes) | Predecessor |
|-----------------------------------------------|----------------|-------------|
| A. Clean the bottle cap, the remaining drugs, etc. | 8              | -           |
| B. Removing the spare part                    | 12             | -           |
| C. Soak part (before)                        | 7              | H           |
| D. Wash parts                                | 26             | C, F        |
| E. Soak part (after) + dry                   | 15             | D           |
| F. Wash holding tank                          | 5              | B           |
| G. Cleaning machines                          | 31             | A, B        |
| H. Preparation of the room and cleaning tools | 3              | G           |
| I. Cleaning of walls                          | 14             | H           |
| J. Clean the glass                            | 17             | I           |
| K. Cleaning the floor                         | 4              | J           |
| L. Dry Room                                   | 7              | K           |
| M. Record in log sheets                       | 7              | F, L        |

The result of the application of the critical path method can be seen in Figure 5.

Figure 5. Critical Path Method

From CPM’s optimal results, it was found that the process of cleaning the filler machine can be completed in a period of 1 hour 28 minutes (excluding record in the log sheet). When compared with the actual work time is 1 hour 53 minutes, then the application of this method can save time by 25 minutes with the work process has been structured.

The division of tasks to the two operators is determined based on the critical activities can be described in Table 4.
Table 4. Division of Tasks Based on CPM

| Task Description                  | Operator 1                                      | Operator 2                                      |
|-----------------------------------|-------------------------------------------------|-------------------------------------------------|
| Removing the engine part          | Cleaning bottle, cap, remaining drug, etc.      |                                                 |
| Cleaning machines                 | Soak the parts (before)                         | Wash holding tank                               |
| Preparing equipment for cleaning  | Wash parts                                      |                                                 |
| the room                          |                                                 |                                                 |
| Cleaning of walls                 | Soak the parts (after) + dry                    |                                                 |
| Clean the glass                   | Setting up the vacuum tool                      |                                                 |
| Cleaning the floor                | Record on log sheet                             |                                                 |
| drying the floor                  |                                                 |                                                 |

4.4. Maynard Operation and Sequence Technique
In this study, the calculation of MOST is divided into three cleaning process, namely cleaning machine, cleaning the room, and cleaning parts. Application of MOST in this study is more focused on the cleaning process and is not applied when the operator cleans the bottle, cap, the rest of the drug, the release of spare parts, and also recording the activities on the log sheet. This is because the cleaning process has a more complex problem.

Time is produced in the form of Time Measurement Unit (TMU) and if converted into units of time, then the result is the normal time. Table 5 is a summary table of MOST calculation results in the form of time TMU and normal time.

Table 5. Maynard Operation and Sequence Technique

| Cleaning Machine                  | A   | B   | G   | P   | M   | X   | I   | S   | C   | TMU | Total Time (minutes) |
|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------------------|
| Total Work Element                | 5190| 34240| 5530| 580 | 460 | 640 | 160 | 2708| 0   | 48640    | 29.184               |
| Non-value added                   | 3.184| 20.544| 3.138| 0.348| 0.276| 0.06| 1.62| 0   | 29.1 |                      |
| Value added                       | 0.084|               |     |     |     |     |     |     |     | 0.084 |                      |

| Cleaning the Room                 | A   | B   | G   | P   | M   | X   | I   | S   | C   | TMU | Total Time (minutes) |
|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------------------|
| Total Work Element                | 9350| 5330| 630 | 680 | 2469| 20  | 230 | 8780| 0   | 27480    | 16.488               |
| Non-value added                   | 5.61| 3.198| 0.378| 0.408| 1.476| 0.338| 5.264| 0   | 16.476 |                      |
| Value added                       | 0.012|               |     |     |     |     |     |     |     | 0.012 |                      |

| Cleaning Parts                    | A   | B   | G   | P   | M   | X   | I   | S   | C   | TMU | Total Time (minutes) |
|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------------------|
| Total Work Element                | 4560| 20720| 7510| 9159| 1109| 870 | 370 | 1660| 1508| 47520 | 26.512               |
| Non-value added                   | 2.736| 12.452| 4.518| 5.49 | 9.66 | 0.222| 0.996| 0.936| 27.09| 0.522 |                      |
| Value added                       | 0.555|               |     |     |     |     |     |     |     | 0.522 |                      |

It can be seen in Table 5 that the process takes a lot more to be done is cleaning machines for ± 29 minutes and engine parts for ± 28 minutes. Cleaning the room normally can be done within ± 16 minutes. Thoroughness in cleaning machines and parts is needed thoroughness in the cleaning process because if there is an error then it can cause damage or loss. Besides, machine and parts have to be cleaned as well as possible because it will be reused for the production process afterwards. When viewed from the observation that has been done, cleaning the machine requires quite a long time because the equipment for cleanliness inadequate.

According to Table 5, the highest index parameter is B (Body Motion) which means that B has high motion waste. Several wastes in body motion are bending when taking water to rinse the machine, climbing a chair to clean high positioned window, bending to clean machine parts. In order to move effectively, the operators have to use the additional tools.

4.5. Allowance and Standard Time
To calculate the standard time it takes the data allowances each operator. Allowance is looseness interpreted as tolerance to rest to overcome fatigue or to factors that cannot be avoided. The value of the allowance can be seen from the ILO recommended allowances. Each cleaning process produces
different allowances. Table 6 shows the difference between allowances and the calculation results of standard time at each cleaning process.

Table 6. The Result of Allowances and The Standard Time

| No | Activity          | Time (TMU) | Normal Time (min/seconds) | Allowances (%) | Standard Time (minutes) |
|----|-------------------|------------|--------------------------|----------------|-------------------------|
| 1  | Cleaning Machine  | 48640      | 29,184                   | 25%            | 38.912                  |
| 2  | Cleaning the Room | 27480      | 16,488                   | 21%            | 20.857                  |
| 3  | Cleaning Parts    | 47520      | 28,512                   | 27%            | 39.057                  |

MOST is used to set the standard time [13]. Based on Table 6, the standard time has been obtained. The total standard time for the cleaning process is 98.826 minutes or 1 hour 38.826 minutes. It can be a time reference for Company X in the process of cleaning.

If the cleaning process can be adapted to the standard time and the division of tasks in parallel to both operators, it is expected that the time for the cleaning process can be faster and increase the value of OEE through increased availability.

The results of this research shows that time study methods, such as MOST, is effective in reducing time in pharmaceutical industry setting. The result is accordance with other MOST research results [12, 13] and other time study method research results [14 - 16].

5.  Conclusion and Suggestions

The findings show that CPM and MOST can decrease the cleaning process time of the filler machine. Based on the results of Critical Path Method for filler machine, the time to complete the cleaning process is reduced to 1 hour 28 minutes. It is 25 minutes faster than the current time of the cleaning process, which is 1 hour 53 minutes. With the Maynard Operation and Sequence Technique, the standard time for the cleaning machines is 38.912 minutes, 20.857 minutes for room, and 39.057 minutes for engine parts. The total standard time for the cleaning process is 1 hour 38.826 minutes. We suggest the company to make the work procedures specific to the division of tasks activity based on Critical Path Method along with the target time of the cleaning process in accordance with the standard time.

Wastes in body motion happens because the operators do not utilize the existing cleaning equipment properly. We suggest the company to pay attention to this problem by providing regular training to the operators to use the existing cleaning equipment properly, such as to use a hose to rinse the machine and extension stick for cleaning parts in high places.

References

[1] Frost & Sullivan’s Industrial Automation Practice 2005 *Improving Plant Performance: Overall Equipment Effectiveness* (Frost & Sullivan)
[2] Karad AA, Waychale NK and Tidke NG 2016 *Int. J. of Eng. Res. & Gen. Sci.* 4 657-62
[3] Sudri NM and Mareti A 2012 *J. Tek. & Ilm. Komp.* 1 88-98
[4] Almeanazel OTR 2010 *Jord. J. of Mech. & Indust. Eng.* 4 517-22
[5] Niebel BW and Freivalds A 2009 *Niebel’s Methods, Standards, and Work Design* (New York: Mc-Graw Hill)
[6] Heizer J and Render B 2011 *Operations Management* (New Jersey: Prentice Hall)
[7] Sahid DSS 2012 *J. Tek. Inf. & Tel.* 5 14-22
[8] Barnes RM 1980 *Motion and Time Study: Design and Measurement of Work* (New York: John Wiley & Sons)
[9] Mishra A, Agnihotri V and Mahindru DV 2014 *Glob. J. of Res. in Eng.* B 14 1-7
[10] Sutalaksana IZ, Anggawisastra R and Tjakraatmadja JH 2006 *Teknik Perancangan Sistem Kerja*
(Bandung: Penerbit ITB)

[11] Jamil M, Gupta M, Saxena A and Agnihotri V 2013 *Glob. J. of Res. in Eng. Mech. & Mech. Eng.* **13** 45-56

[12] Puvanasvaran AP, Mei CZ and Alagendran VA 2013 *Proc. Eng.* **68** 271-7

[13] Pandey A, Deshpande VS and Gunjar S 2016 *Int. J. of Inno. in Eng. and Tech.* **6** 39-44

[14] Al-Saleh KS 2011 *J. of King Saud Univ. – Eng. Sci.* **23** 33-41

[15] Yusoff N, Jaffar A, Abbas NM and Saad NH 2012 *Proc. Eng.* **41** 1800-5

[16] Duran C, Cetindere A, Aksu YE 2015 *Proc. Econ. and Fin.* **26** 109-13