Evaluation of turnaround maintenance practice effects in the process industry

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Abstract. Process industry such as the petrochemical industry is a kind of industry where the production performance depends on production equipment and assets. Thus, preventive maintenance becomes a very important way to achieve sustainable production in the process industry. The effectiveness, efficiency, reliability and maintenance of the equipment are vital for the uninterrupted, continuous and efficient operation. Turnaround maintenance (TAM) plays the most important role of preventive maintenance activities because it is an essential activity of maintenance in the process industry to improve the availability and reliability of the assets includes plant facilities, equipment and machinery. This study evaluates the effect of Turnaround Maintenance on the condition of the assets in the process industry using the statistical method. The significant variables used to analyze the effect of TAM are Plant Availability and Downtime Loss. The result shows that the correlation value between TAM occurrences with the increasing of availability is 0.315 and with the increasing of downtime loss is -0.818. The correlation value proves that TAM have a significant effect to increase the availability of the plant and to decrease the downtime loss in the real process industry practice.

1. Introduction
Process industry such as the petrochemical industry is a kind of industry where the production performance depends on production equipment and assets. Thus, maintenance becomes a very important way to achieve sustainable production in the process industry. The effectiveness, efficiency, reliability and maintenance of the equipment are vital for the uninterrupted, continuous and efficient operation.

Types of preventive maintenance activity applied in the process industry generally are Routine Preventive Maintenance (when the plant is on), Turnaround Maintenance (Shutdown Preventive maintenance), and Inspection. Turnaround maintenance (TAM), as big part of preventive maintenance, plays the most important role of preventive maintenance activities because it is an essential activity of maintenance in the process industry to improve the availability and reliability of the assets includes plant facilities, equipment and machinery.

The TAM evaluation methods had been proposed to ensure the sustainable and effective TAM were conducted in the industrial plants. Generally, the evaluation methods were considering the management and technical aspect of TAM activities, but there is no study considering the direct effect of conducting TAM to the plant condition and its availability yet. While, the study of this effect may be used to evaluate TAM effectiveness with the different point of view and to prove that TAM is a right choice for the process industries to keep the plant condition and production effectivity as high as possible, as well as
reducing the downtime loss due to corrective maintenance and breakdowns. This research conducted to fill in the gap among TAM evaluation methods had proposed, by analyzing the effect of TAM on the availability of the plant and the downtime loss.

2. Turnaround Maintenance in the Process Industry

2.1. Overview

Turnaround maintenance (TAM) is an essential activity in the process industry. It plays an important role in maintaining consistent productivity, increase reliability, reducing maintenance cost due to corrective maintenance and breakdowns, and managing resources more efficiently [1]. The main focus of TAM is to keep maintenance cost at the lowest level and production efficiency at the highest possible level [1]. It is being seen as a major project that requires sound planning, execution and control.

Although different TAM may have different specific objectives, generally the main objectives for TAM are to increase reliability/availability of equipment during operation, to make the plant safe to operate till next TAM, and improve efficiency and throughput of the plant by suitable modification and upgrade technology [2].

By definition, Turnaround maintenance (TAM) is periodic maintenance in which plants are shutdown to allow for inspections, repairs, replacements and overhauls that can be carried out only when the assets (plant facilities) are taken out of service [3]. There are three types of works that perform during TAM: Work on equipment that only can be done when the plant is shutdown, work that may be done when the plant is in operation but requires long period and a large number of maintenance personnel, and defects that are found during operation, but could not be repaired. TAM projects have different size, duration and particular specifications depend on the actual industry site. TAM of the large plant may take in total up to one year and must be repeated every four to six years [4]. Turnarounds (TA) represent a significant expense for companies, both in term of loss in revenue as well as direct turnaround costs (manpower, equipment and parts). As a result, TAM is tightly coupled to production planning, resource planning and inventory management decisions [5]. TAM is considered as an engineering event of relatively short duration, but it is only one segment of a cyclical process with those four phases [6].

The consideration of seeing TAM as an engineering project given by seeing that TAM is always conducted in a certain short period, and have the different main task of maintaining certain part of the plant for each TAM period depends on the result of the inspection on the plant [7,8]. Meanwhile, TAM also has been seen as routine maintenance because its schedule, general tasks and activities are part of preventive maintenance actions during the shutdown of the plant [3,7,9,10].

2.2. Turnaround Maintenance Evaluation

Based on the previous researches and studies, TAM can be seen as a project, a big part of preventive maintenance activity or both. The methods for TAM evaluation or TAM success measurement are classified based on the way of seeing TAM. The evaluation of TAM is essential for continuous improvement and success in conducting TAM [2].

Many previous works modeled TAM as a maintenance project contains a huge number of precedence-constrained operations or jobs that must be executed by maintenance groups of different specializations [4,11,12]. TAM is a big complex and broad scope maintenance engineering project that requires many resources and conducted under limited time and budget [4]. In general, the project management body of knowledge applies to TAM [2]. Therefore, the TAM project success can be evaluated using management success evaluation (time, cost, quality, health and safety), and TA team (top management and participants) expectations. Those measurement criteria are therefore necessary not only to assist in identifying the factors that affect TAM project success but also to ensure correct evaluation of the TAM project outcome [8]. Otherwise, some researches modeled TAM as part of routine preventive maintenance, because major maintenance activities in TAM are scheduled and planned preventive maintenance actions [10].

The TAM evaluation methods had been proposed to ensure the sustainable and effective TAM were conducted in the plant industries. Most evaluation theories concern to measure the performance of TAM
conducted from the side of management and technical of TAM process and execution. There is no certain method in the literature about evaluating TAM by measuring the effect of entire TAM conducted to the plant performance. As mentioned before, some TAM main objectives related plant performance is bringing the plant to their original health; making the plant machines safe to operate; reduction of routine maintenance costs; and increasing the reliability/availability of equipment during operation [1,2,8]. The previous evaluation methods were able to show how efficient and effective TAM conducted management and technically. However, even TAM process and execution is conducted effectively and efficiently, it does not mean that the maintenance tasks applied to the plant (include equipment and assets) during TAM, were optimum to improve plant condition to its original health; increase its availability and reduce its downtime. The optimum TAM should fulfil its objectives. It means, TAM can be considered optimum when the plant availability is increased and the downtime is decreased after TAM conducted to the plant.

3. Methodology
The methodology of this research may be explained as below:

3.1. The proposed TAM evaluation
The study considering the direct effect of conducting TAM to the plant condition and its availability might become another point of view of evaluating TAM. The method proposed also could be a proof that TAM is a right choice for the process industries to keep the plant condition and production effectiveness as high as possible, as well as reducing the downtime loss due to corrective maintenance and breakdowns. Those proofs can be a significant reason for the process industry to attempt sustainable and continuous TAM to their process plants, equipment and assets.

The variables chosen to analyze the effect of TAM in this study are Plant Availability and Downtime Loss. Those variables are used to evaluate general Preventive Maintenance performance and suitable to be used to TAM as part of preventive maintenance activity [13]. The Plant Availability value represents the condition and availability of the asset, while Downtime Loss shows the losses due to corrective maintenance and breakdowns. The gap between target values and actual production values shows the downtime loss. Downtime loss can be defined in currency, units of product, or time [14]. The lower downtime loss means higher reliability of the plant.

3.2. Data Collection
The case study company (CSC) is one of the big fertilizer company in Indonesia. As a process industry, the CSC really concern on the maintenance of their plants. The CSC consist of 5 fertilizer production plants. Despite the regular maintenance, the CSC also conduct the turnaround maintenance (TAM) for a minimum of twenty-one (21) days for each plant every two years.

This research conducted to one of the plants, called Ammonia K-3 plant because it is the role model plant for applying and improving their Preventive Maintenance Management Method, called Reliability-centered Maintenance (RCM). Regarding TAM practice in the company, PKT is still wondering about the direct effect of the TAM activity to the plant. Currently, the TAM evaluation in the company is about the management and technical aspect of the TAM process and execution. The evaluation is written in the Turnaround Report and presented to the company management as consideration for the following Turnaround activity and budget. To show whether the TAM practice in the company is optimum or not to fulfill the objective of the TAM, the quantitative analysis showing the correlation between TAM occurrence and condition of the plant afterward, is done in this study.

The data used for calculating Plant Availability and Downtime Loss is obtained from company Monthly Asset Utilization (MAU) Report, from the year 2001 to 2017. From the MAU report, Table of Recapitulation of Production Loss consisting speed loss, planned downtime and downtime loss every month is combined into annual data. The annual Actual Production (AP) and details of unplanned downtime or breakdown also obtained from MAU Report.

The formula used to calculate Plant availability value and Downtime Loss are [14]:

\[
\text{Operation Time} = \text{Base Production Time} - \text{Planned Downtime} \quad (1)
\]
\[
\text{Loading Time} = \text{Operation Time} - \text{Unplanned Downtime} \quad (2)
\]
\[
\text{Production Rate} = \frac{\text{Actual Production}}{\text{Loading Time}} \quad (3)
\]
\[
\text{Downtime Loss} = \text{Total Downtime} \times \text{Production Rate} \quad (4)
\]

To evaluate the effect of TAM to the plant condition in the next following year, the correlation should be done between TAM occurrence in (t-1) year with the change (\(\Delta\)) of the variables from (t-1) to (t) year.

The \(\Delta\) is calculated by the following equation:
\[
\Delta \text{ Availability} = \text{Availability} (t) - \text{Availability} (t-1) \quad (5)
\]
\[
\Delta \text{ Downtime loss} = \text{Downtime loss} (t) - \text{Downtime loss} (t-1) \quad (6)
\]

3.3. The Statistical Method: Point-Biserial Correlation

The statistical method called The Point-Biserial Correlation is used to calculate the correlation between the presence of TAM and the delta value of availability and downtime loss. This method is chosen because the Point-Biserial Correlation Coefficient is a correlation measure of the strength of association between a continuous-level variable (ratio or interval data) and a binary variable. Mathematically, the Point-Biserial Correlation Coefficient is calculated just as Pearson’s Bivariate Correlation Coefficient would be calculated and all correlation coefficients are interdependency measures that do not express a causal relationship [15,16]. Coefficient measures the strength of association of two variables in a single measure ranging from -1 to +1, where -1 indicates a perfect negative association, +1 indicates a perfect positive association and 0 indicates no association at all. In this study, the binary variable is the occurrence of TAM and the continuous-level variables are the change of Plant Availability and Downtime Loss.

4. Result, Analysis and Discussion

The TAM occurrence and the calculation result of the Plant Availability, Downtime Loss, \(\Delta\) Availability and \(\Delta\) Downtime loss are shown in Table 1.

| Year | TAM Occurrence | Availability | Downtime Loss (ton) | TAM Occurrence (t-1) | \(\Delta\) Availability | \(\Delta\) Downtime Loss |
|------|----------------|--------------|---------------------|----------------------|-------------------------|------------------------|
| 2001 | 1              | 0.88         | 61126.0             |                      |                         |                        |
| 2002 | 0              | 0.97         | 11499.1             | 1                    | 0.091                   | -49626.9               |
| 2003 | 1              | 0.99         | 41118.7             | 0                    | 0.019                   | 29619.6                |
| 2004 | 0              | 0.95         | 16057.0             | 1                    | -0.031                  | -25061.6               |
| 2005 | 0              | 1.00         | 0.0                 | 0                    | 0.045                   | -16057.0               |
| 2006 | 1              | 0.97         | 40728.0             | 0                    | -0.034                  | 40728.0                |
| 2007 | 0              | 0.98         | 7092.0              | 1                    | 0.015                   | -33636.0               |
| 2008 | 1              | 0.97         | 26631.8             | 0                    | -0.008                  | 19539.8                |
| 2009 | 0              | 1.00         | 310.0               | 1                    | 0.026                   | -26321.8               |
| 2010 | 1              | 0.98         | 27000.0             | 0                    | -0.018                  | 26690.0                |
| 2011 | 0              | 1.00         | 0.0                 | 1                    | 0.019                   | -27000.0               |
| 2012 | 0              | 0.99         | 3028.6              | 0                    | -0.008                  | 3028.6                 |
| 2013 | 1              | 0.98         | 17399.7             | 0                    | -0.008                  | 14371.1                |
| 2014 | 0              | 0.98         | 6768.0              | 1                    | -0.002                  | -10631.7               |
The visual comparison of TAM occurrence and the value of Plant Availability and Downtime Loss can be seen in figure 1 and figure 1. As seen in figure 1, the availability value tends to increase in the following year after TAM is conducted in the plant. Meanwhile, as for figure 3, the downtime loss tends to decrease in the following year after TAM is conducted in the plant. But then, the effect of TAM occurrence on the Plant availability and Downtime loss need to be analyzed quantitatively to show the effect of TAM occurrence to the increase of availability and the decrease of downtime loss.

Figure 1. The Graph of Availability value and TAM occurrence.

Figure 2. The Graph Downtime Loss and TAM occurrence.
The calculation is done using SPSS as the statistical tool to obtain the correlation value. The input value of the SPSS are TAM occurrence (t-1), ΔAvailability and ΔDowntime loss. The result of the calculation in SPSS is shown in table 2. The correlation value between TAM occurrences with the increasing of availability is 0.315. The positive value of the correlation coefficient shows the positive association between TAM occurrence and the Δ Availability, which means the TAM occurrence has an effect to increase the Plant Availability value. The correlation value between TAM occurrences with the Δ Downtime loss is -0.818. The minus value indicates the negative association between TAM occurrence and the Δ Downtime loss, which means the TAM occurrence has an effect to decrease the Downtime Loss.

Table 2. The result from SPSS.

|                      | delta_TA Pearson Correlation | delta_availability | delta_DL Pearson Correlation |
|----------------------|------------------------------|--------------------|-----------------------------|
|                      | 1                            | .315               | -0.818**                    |
| Sig. (2-tailed)      |                              | .235               |                            |
| N                    | 16                           | 16                 | 16                          |

**. Correlation is significant at the 0.01 level (2-tailed).

It can be concluded that TAM activities of the assets have a significant effect to increase the availability of the plant and to decrease the downtime loss. It proves that in the real process industry practice, TAM does improve the availability and reliability of the assets.

The method proposed in this study may be the new way to evaluate the TAM practice in the process industry. The nearer the value to zero means TAM might be not significant to change the Plant Availability and Downtime Loss and indicate that the TAM conducted in the plant is not fulfilling the TAM main objective to increase the plant condition and reliability. The TAM process, tasks and execution should be evaluated further to optimize and improve TAM effect to the Plant, equipment and asset.

5. Conclusions and Recommendations
The method proposed in this study may become a different point of view to evaluate TAM practices in the process industry. The statistical method to calculate the correlation of TAM occurrence to Plant Availability and Downtime Loss was able to indicate the effect of TAM on the plant condition. The correlation value proves that TAM has a significant effect to increase the availability of the plant and to decrease the downtime loss. The high value of the correlation shows the TAM practice is optimum to improve the condition of the plant by increasing the availability and decreasing the downtime. It proves that TAM does improve the availability and reliability of the plant in the real process industry practice.

Further study related the statistical method to evaluate TAM practice in the industries is highly possible regarding there is still very view research conducting on this topic.

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