Proposing predictive maintenance strategy to increase OEE through system upgrade scenarios and AHP

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Abstract. Maximizing the value of OEE is a crucial thing to do for a company in order to increase their productivity. OEE is one of the most common technique to measure equipment’s effectiveness. To enhance the number of OEE, it is very important to do a maintenance task to keep the equipment in a good condition. Predictive maintenance task is one of the maintenance strategies to see any potential failure in an equipment and do a preventive way to prevent it from a total stop/break down. As a result, understanding the needs to do a maintenance upgrades for better performance and proposing a good predictive maintenance strategy will enhance the value of OEE and result in cost savings. The objective of this paper is to propose the necessary predictive maintenance task using analytical hierarchy process (AHP) using three respondents to decide the AHP process and consistency ratio to get the most suitable maintenance task for fertilizer company as small medium enterprise.

1. Introduction
In the current era of globalization where there are no boundaries between nations in various matters throughout the world including competition in the economic and business, manufacturing sector is one of the most crucial field in helping to improve the economic growth of a country. Based on this fact, many companies are competing to be able to provide the best manufacturing performance and continuous improvement by maximizing the effectiveness of the manufacturing process [1]. Companies are starting to look for some techniques in order to enhance the excellence of the manufacturing process and improving the overall performance. Thus, it will help reducing the cost to gain more profit to the company. One of the things that needs to be considered in improving the effectiveness of the manufacturing process is maximizing the utilization of the equipment. The most common technique to measure the effectiveness of equipment is Overall Equipment Effectiveness (OEE) which is a part of Total Productive Maintenance (TPM) [2]. TPM strives to improve productivity and reduces losses by doing an appropriate maintenance [3]. OEE is a calculation tool to provide information about the process using multiple data and issues in manufacturing. OEE delivers a framework to improve manufacturing process in a company. Efficiencies can be improved by using the six big losses as in OEE concept. The Component in OEE are Availability, Performance Rate and Quality [4]. By improving quality product, time and efficiencies will help to gain customer’s satisfaction [5].

The other things to be considered in maximizing the overall equipment effectiveness is by doing maintenance task. Unplanned downtime in a machine can cause delays and reduce the productivity of an equipment. Thus, it will also reduce the OEE value. One of the maintenance actions that can be applied is predictive maintenance. Predictive Maintenance is a maintenance task to see the potential problem of an equipment by looking at the historical data and analysing the pattern. By detecting the potential failure earlier, it can also reduce the cost for maintenance.

By knowing the performance issues, the predictive maintenance strategy can be formed by integrating all the system and doing scenario upgrades for better improvement in enhancing the value of OEE and predicting how long the strategy will last.
Fertilizer company is one of the most important part of Indonesia as an agricultural country. It takes part to help farmer on providing the best food for the society. Based on the data of the fertilizer producer association, the need of fertilizer increased 5% along 2018 for about 6,27 million from the initial number 5,97 million in 2017. It is necessary to keep the production going with minor interruption. Maintenance task could be a very important and beneficial role to increase machine’s ability and enhance the number of OEE. Maintenance strategy for such a big fertilizer company maybe already good, but how to choose a good maintenance task which fit with the machine’s characteristic for small medium fertilizer companies? Most of them still not familiar with the expert maintenance strategy by extending the maintenance activities or doing the cost reduction for breakdown maintenance.

The objective of this paper is to propose a predictive maintenance strategy in order to enhance the value of overall equipment effectiveness using system upgrade scenarios and analytical hierarchy process (AHP) method to select some maintenance alternatives to be implemented in a company based on some important criteria. AHP is a method used to make an order of decision and alternatives to get the best decision. The main input of AHP is human perception. AHP would be beneficial to know which task is better than another task by using expert judgment and consistency ratio calculation. It’s easier for small medium fertilizer company to be applied rather than focusing on detecting maintenance task using reliability centered maintenance (RCM), the well-known method for maintenance. Since there is no any quantitative procedure in AHP, it is very necessary to choose an expert for doing the AHP process to make it more relevant. AHP is commonly used in any sector since it is not a new method in industry.

2. Methods
As stated previously, the method used in making this paper is by analysing the upgrades needed by understanding the preparation for upgrades scenarios, then, mapping the predictive maintenance task and linked it with six major losses in Total Productive Maintenance (TPM) concept. By using Analytical Hierarchy Process (AHP) as the multicriteria decision tools, we try to propose the best predictive maintenance task importance priority for company. These two methods is not a new method, but we combine of two existing method.

2.1. Analysing Upgrade Scenarios
An upgrade is necessary for a company especially if it affect the productivity. The first thing to do is understanding the reason to do an upgrade and why is it necessary to be applied to the company. For this step, a focus group discussion involving all the stakeholder can be taken as an alternative. Planning the upgrade strategy and scenarios for the company should be depend on the business case. In this paper, it is about the performance issues and in order to enhance the OEE value of an equipment. The strategy should be made after we analyse the benefit of implementing updates by comparing the cost for upgrade and its profit for the company. The next phase is determining the readiness and the path for upgrade and scope the project. This paper aim to scope the project on predictive maintenance task upgrade by selecting some necessary task to minimize the cost but still fulfilling all the needs for predictive maintenance. Since it’s also a qualitative research, the respondent must be someone who really takes part and involve in maintenance activity of the company. It should be a head of maintenance division, senior field staff of maintenance, head of production division and the machine’s operator. They are responsible for the production and maintenance. The combination for these four respondents will help us to use the AHP to choose the best maintenance task to enhance the production. These all four experts who can make this research become more relevant since it’s a qualitative research. Thus, the combination of technical procedure and expert judgment will give the expected optimum result of cost reduction and maximizing performance.

2.2. Mapping the Predictive Maintenance Task
Mapping the predictive maintenance task by understanding its importance and involving all stakeholder is one of the most crucial things to do. The predictive maintenance task should consist of plan, do, check, and action concept. Action proposed in predictive maintenance task shows in Table 1.
Table 1. Predictive maintenance task & maintenance task cost in a fertilizer company.

| No | Predictive Maintenance Task                          | Cost Spend/year |
|----|-------------------------------------------------------|-----------------|
| 1  | Vibration monitoring                                  | $ 1,500         |
| 2  | Thermographic inspection                             | $ 1,200         |
| 3  | Oil analysis                                          | $ 3,000         |
| 4  | Visual inspection                                     | -               |
| 5  | Shock pulse                                           | $ 2,700         |
| 6  | Ultrasonic leak detector                             | $ 1,700         |
| 7  | Electrical insulation                                 | $ 2,900         |
| 8  | Performance testing                                   | $ 3,200         |
| 9  | Wear and dimensional measurement                      | $ 700           |
| 10 | Signature analysis, time, and frequency domain        | $ 600           |
| 11 | Non-destructive testing by using ultrasonic          | $ 800           |

By knowing the predictive maintenance task, we can link it with six major losses in TPM based on the value of OEE. Table 2 shows the relation between maintenance task and their effect on six big losses. It shows whether the activity give big impact to the losses or not. The six big losses including unplanned stops, planned stops, small stops, slow cycle, production reject and start-up reject [6]. Each loses represent the element for overall equipment effectiveness which are availability loss, performance loss, and quality loss.

Table 2. OEE components.

| Overall Equipment Effectiveness | Six Big Losses               | Conventional Six Big Losses |
|---------------------------------|------------------------------|------------------------------|
| Availability Loss               | Unplanned Shutdown           | Machine Failure              |
|                                 | Planned Shutdown             | Machine Adjustments          |
| Performance Loss                | Idle Time                    | Machine Idle                |
|                                 | Slow Speed                   | Speed Reducing               |
| Quality Loss                    | Product Rejection            | Product Defect               |
|                                 | Start-up Rejection           | Yield Reducing               |
| OEE                             | Total Productive Time        | Valuable Operational Time    |

Source: Nakajima, 1990

2.3. Using Analytical Hierarchy Process

The analytic hierarchy method (AHP), is a powerful multicriteria decision-making tool. It was developed by Saaty and has been applied in many field including economics, engineering and even politics [7]. This method will help the decision maker to assign some value/weight which represent preferences of some given alternatives so that one best possible alternative will be chosen as the most weighted alternatives. This method allows decision maker to make some decisions in an objective way based on the decision maker point of view by the appropriate ranking for each alternative with some criteria. The importance level of each criteria is not the same. Thus, the next step to do is proposing the relative weight for all criteria [8]. Using paired comparison, the decision maker will be able to express their preference for each criterion [9]. The AHP process started by forming the hierarchy in form of tree and connecting some decision element with other component such as main objectives and criteria of alternatives solution [10]. The next phase is doing the comparison between the criteria importance and variants of decision element [10]. Table 3 explain the dependencies between criteria, and explanation for each scale shows in Table 4.
Table 3. Linked between maintenance task and six big losses.

| Maintenance Task | Equipment failure | Setup and Adjustment | Idling and Minor Stop | Reduced speed | Process defect | Reduces yield |
|------------------|-------------------|----------------------|----------------------|---------------|---------------|--------------|
| 1 Vibration monitoring | V                  |                      | V                    |               |               |              |
| 2 Thermographic inspection | V                  |                      | V                    |               |               |              |
| 3 Oil analysis | V                  | V                    | V                    |               |               |              |
| 4 Visual inspection | V                  | V                    | V                    | V            |               |              |
| 5 Shock pulse | V                  |                      |                      | V            |               |              |
| 6 Ultrasonic leak detector | V                  |                      |                      | V            |               |              |
| 7 Electrical insulation | V                  |                      |                      | V            |               |              |
| 8 Performance testing | V                  | V                    | V                    | V            | V            | V            |
| 9 Wear and dimensional measurement | V                  |                      | V                    | V            | V            |              |
| 10 Signature analysis, time, and frequency domain | V                  |                      | V                    | V            | V            |              |
| 11 Non-destructive testing by using ultrasonic | V                  |                      |                      | V            |               |              |

Table 4. Explanation for each scale.

| Scales | Degree of Preferences | Explanation |
|--------|----------------------|-------------|
| 1      | Equally              | Two activities contribute equally to the objectives |
| 3      | Moderately           | Experience and judgement slightly to moderately favour one activity over another |
| 5      | Strongly             | Experience and judgement strongly or essentially favour one activity over another |
| 7      | Very Strongly        | An activity is strongly favoured over another and its dominance is showed in practise |
| 9      | Extremely            | The evidence of favouring one activity over another is of the highest degree of possible of an affirmation |
| 2,4,6,8| Intermediate Values  | Used to represent compromises between the preferences in weights 1, 3, 5, 7, 9 |
| Reciprocals | Opposite            | Used for inverse comparison |

Since this method contains high subjectivity, it is necessary to count Consistency Ration (CR) using this formula

\[ CR = \frac{CI}{RI} \]  

Where

\[ CI = \frac{\lambda_{max} - n}{n-1} \]  

While RI represents parameter based on the number of matrix element. If the number of CR is less than 0.1 or equal to 10\% of average inconsistency, the judgement is usually acceptable. If it is more than 0.1 or 10\%, the judgement should be revised [11]. Table 5 shows weights of the criteria based on pairwise comparison.
Table 5. AHP results.

| No | Predictive Maintenance Task                              | Priority | Rank |
|----|----------------------------------------------------------|----------|------|
| 1  | Vibration monitoring                                     | 0.117    | 3    |
| 2  | Thermographic inspection                                 | 0.1      | 5    |
| 3  | Oil analysis                                             | 0.119    | 2    |
| 4  | Visual inspection                                        | 0.6      | 10   |
| 5  | Shock pulse                                              | 0.104    | 4    |
| 6  | Ultrasonic leak detector                                 | 0.098    | 7    |
| 7  | Electrical insulation                                    | 0.099    | 6    |
| 8  | Performance testing                                      | 0.126    | 1    |
| 9  | Wear and dimensional measurement                         | 0.062    | 9    |
| 10 | Signature analysis, time, and frequency domain           | 0.065    | 8    |
| 11 | Non-destructive testing by using ultrasonic             | 0.005    | 11   |

*Consistency ratio: 9.3%

Depend on the comparison above, the consistency ratio result is 9.3%. It means that the judgement made is acceptable because it is still under 10%.

3. Result and Discussion

Doing maintenance task is a very important things to do for a company. But there are several maintenance tasks which is not really relevant to detect a problem in an equipment. Besides, it is sometimes too expensive especially for a small and medium enterprises which still trying to survive in market. After mapping the maintenance task and find the preferences of each alternatives, we found several maintenance tasks which is necessary and give high impact to detect the equipment’s problem. Based on the analytical hierarchy process, we found that the maintenance task with the highest rank is performance testing. It is shown on the table. that it can affect all the six big losses. By doing performance testing we can understand clearly whether the equipment is still in a good condition or not. This task represents all testing for the equipment. If the performance decrease, it should be that the equipment is on trouble and decrease on its reliability. The company should choose the best and most relevant maintenance task.

In the table above, we can see the rank of each predictive maintenance task. The three highest position are doing performance testing, oil analysis and vibration analysis. This is the cost need supposed if we want to do an upgrade by implementing just the five highest rank.

Implementing only several maintenance task which represent the whole maintenance for an equipment will able to save the cost for maintenance and also enhance the OEE value. As we know this task already suit the predictive maintenance strategy which is scheduled on condition and failure finding task.

Table 6. Maintenance task rank based on pairwise comparison.

| No | Maintenance Task                               | Rank |
|----|-----------------------------------------------|------|
| 1  | Performance tasting                           | 1    |
| 2  | Oil analysis                                  | 2    |
| 3  | Vibration analysis                            | 3    |
| 4  | Shock pulse                                   | 4    |
| 5  | Thermographic inspection                      | 5    |
| 6  | Electrical insulation                         | 6    |
| 7  | Ultrasonic leak detector                      | 7    |
| 8  | Signature analysis, time, and frequency domain| 8    |
| 9  | Wear and dimensional measurement              | 9    |
| 10 | Visual inspection                             | 10   |
| 11 | Non-destructive testing by using ultrasonic   | 11   |
Table 7. Cost saving after AHP.

| No | Maintenance Task            | Cost Spend/Year |
|----|-------------------------------|-----------------|
| 1  | Performance testing           | $3,200          |
| 2  | Oil analysis                  | $3,000          |
| 3  | Vibration analysis            | $1,500          |
| 4  | Shock pulse                   | $2,700          |
| 5  | Thermographic Inspection      | $1,200          |

Table 8. Cost comparison before and after the upgrades.

| Cost Before Upgrade | Cost After Upgrade | Cost Savings |
|---------------------|--------------------|--------------|
| $18,300             | $11,600            | $6,700       |

Doing an upgrade can spend around $6,700 each year for the company’s maintenance task. Since we got the top five maintenance task which is relatable with the machine’s characteristic based on expert judgement using AHP. As we seen before the connection between each maintenance task with the OEE component, we justify that the number of every losses will be minimum. This maintenance task is enough to prevent systems from unplanned breakdown and enhance the number of system’s availability. Thus, we hope by increasing the number of availabilities, it will also enhance the number of OEE for the system. Since by the formula of OEE we can see that there’s three factors affecting OEE which are availability, performance and quality. We hope by providing this simple model will be helpful and can be applied for small medium enterprises to enhance their capability in minimizing the unplanned breakdown.

4. Conclusion

Based on the result of AHP, it is shown that performance testing is the most important task to do in predictive maintenance. Implementing upgrades and proposing necessary predictive maintenance strategy can save cost of maintenance around $6,700 each year for a company and still helping in predicting potential failure in order to enhance the value of OEE. But it’s necessary to choose the most suitable respondent to make it relevant. Due to the lack of information, the real implementation and experiment cannot be taken because it will consume much time and cost.

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