Proposing a More Efficient Maintenance Scheduling for an Overhaul Maintenance Project in Engineering Asset Management

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Abstract. In maintenance activity, scheduling planning is an important step to improve the performance of maintenance department. In some cases, the data to support the process to develop the maintenance schedule is unavailable. In this research, it is argued that Genetic Algorithm (GA) is an appropriate tool to support the decision maker in order to develop the schedule. The data required in this research is obtained from the maintenance data in the sugar milling company in Yogyakarta. The company run the production of sugar and spirits/alcohol. The Production process (milling season) is usually performed within the harvesting months of the raw material: the sugar cane. It is approximately in the month of February to August. On the other hand, the overhaul maintenance process is performed after the milling season. The overhaul maintenance planning is created by the manager of the maintenance department, and usually is done using the manager qualitative approach without any scientific approach. To get a more efficient schedule of maintenance, several parameters are set in this research. The parameters are then applied as the parameters in GA. Those are: The number of manpower required and the duration of operation each activity. To run the GA model, Python programming is used. Before start the GA process, the parent chromosom and its fitness are determined. The date of maintenance activity start per each activity is set as the parent chromosome and the fitness is determined using a formula. The process of finding the better maintenance schedule is then performed based on the procedures in GA. It is indicated from the result that the proposed schedule generated in GA required less number of manpower.

1. Introduction

To compete in the competitive business environment, manufacturing industries are forced to improve their performance to achieve the competitiveness advantage. One way to improve the overall performance is to manage the asset effectively. The value of the asset has become the opportunity for an organisation to sustain in the market. The market prefers to have companies who capable to fulfil the required demand, desired quality, and also with on-time delivery. It is a reasonable basis for any company to innovate product with high quality with short lead time and to create a robust production system as a basic
requirement to achieve the better operation process [1]. Based on the data presented by [2], the growth of sector of manufacture increases by 4% in 2016 and create tougher competitiveness environment.

In order strengthen the competitive advantage, the manufacturing company should continuously improve the efficiency and effectivity in their process. One commonly used approach for this purposes is lean manufacturing [3]. Lean manufacturing is a systematic approach to identify and eliminate waste using several improvement tools [4]. Lean manufacturing is capable to produce the desired output with efficient resource used [5]. However, in some point of view, lean is a philosophy and to eliminate the waste other practical tools should be applied. For instance, in the production system the machines have important role to achieve productivity. A high machine reliability is a valuable resources to deliver a good service to the manufacturer [6]. On the other hand, the failure of the machines may lead to the delay of delivery, loss of profit, and miss the opportunity to gain the market for the manufacturer [6]. For this reason, the organisation requires to do maintenance for their asset to keep the performance of the asset and to reduce machine failure.

Maintenance process is performed to provide service to the production facilities and in order to contribute to the process of gaining high productivity [8]. It means that maintenance has a significant contribution to the competitiveness of the manufacture by focusing on the performance of the asset used for production. According to [9], the type of maintenance are planned and unplanned maintenance, depends on the condition of the physical asset. However, in some cases, the requirement of the production process makes obstacles in the implementation of the maintenance strategy.

In Engineering Asset Management, to select an optimum maintenance strategy, every organisation should consider three aspects: performance, risk, and cost associated with the asset. The types of maintenance strategies includes: corrective maintenance, preventive maintenance, and design-out maintenance [10]. Similar with the production process, maintenance process may also generate waste. Carefully observed the maintenence activities leads to the elimination or reduction of the waste. It includes the decision to treat the different machines because the condition of each machine is different. Again, each step in the maintenance process should be analysed in detail to create an effective and efficient process. Process mapping for every flow of the process is necessary to understand the cause of the waste [11].

The focus of this paper is reduce the waste in regard to the overhaul process. The case study is in a sugarcane milling company in Yogyakarta. At this moment, the company performs overhaul maintenance with the support of 60 permanent mechanics and 15 contracted mechanics. The overhaul maintenance should be finished within two months. While this company is implementing maintenance and operation scheduling to reduce the probability of engine damage, this factory did not consider the worker to be allowed to gain the minimum cost. Based on [12], the company gain an opportunity loss of Rp 163,228.00 per minute, and the total per day is Rp. 235,048,320 if production cannot achieve the demand. Maintenance strategy that applied in this factory is preventive maintenance which run in exactly period after the production period. The objectives of this factory to implement this strategy was to avoid the maintenance when the production is running. Therefore, such studies are very important for regulators to detect maintenance project failures when running the maintenance. To identify the beneficiaries of their maintenance, arrangement the scheduling based on the worker allocation and scheduling of maintenance task.

2. Previous Researches on Maintenance Scheduling

Maintenance management is all the management that determines the purpose of maintenance activities, maintenance strategies, and responsibilities along with their implementation [9]. In general, the objectives of care management is divided into 3 major groups, namely [9]:

- Performance
- Risk
- Cost
a. Technical objectives.
   This objective depends on the industrial sector of a business entity operates. In general, the technical objectives of a company are to maintain or increase the availability and operational capability of an asset and improve work safety.

b. Legal objectives/government regulations.
   This objective is set up to cover the quality standard in one project or activity. Legal objectives for normal care management are only to meet the existing rules for various things. This objective arranged by the executive leader and follow the government regulation.

c. Financial goals.
   The financial objective of maintenance management is to meet technical objectives with minimal costs. From a long-term point of view, the overall life-cycle cost of the equipment should be minimal. The objective was urged to implement which the competition of the market to reduce the high operation cost.
   The overhaul maintenance activities in the observed system is considered as an annual project to fulfil the needs of the production process. To avoid the downtime during the production period, the factory applies predictive maintenance as their maintenance strategy. The Maintenance activity is implemented based on the urge of the production process. Preventive maintenance is a treatment carried out by supervising the components/systems so that they are in optimal operational condition by conducting checks, early detection, and systematic improvements before failure or developing a sign of failure in the system [13]. Preventive maintenance objectives include reducing damage to critical components, minimizing production losses due to component failure, and increasing the productive life of a component. Preventive maintenance consists of seven sub activities: inspection, servicing, calibration, testing, alignment, adjustment, and installation.

3. Genetic Algorithm
   Genetic algorithm (GA) is a form of concept or search method that can be used to solve problems and model systems of biological evolution [14]. The implementation used for this study is model in stages such as those in the GA in general. GA is a powerful technique that is used in various fields to find a solution that is almost optimal when searching for the optimal is too expensive. Even though it is attractive and elegant in the laboratory, scalability problems are prevented from being effectively implemented into real problems when GA operation is run.

   GA moves from a population of chromosomes represented in a prospective solution to the new population through three stages, namely: selection, crossover and mutation. Chromosomes are each member of a set that can represent a solution to a problem. Chromosomes are an evolved population in an iteration known as the generation, each chromosome is evaluated based on its evolutionary function (fitness function). The chromosomes will be selected based on each fitness value which has the highest [15].

   There are several things that must be done in genetic algorithms, including the following:
   1. Define individuals: which can be expressed as one solution (solution) of the problem raised.
   2. Define the fitness value: which makes a benchmark whether or not an individual or a solution is achieved.
   3. Determine the initial population generation process: things that are done by random generation.
   4. Determine the selection process to be used.
   5. Determine the crossover process and the mutation of the gene to be used.

   In each iteration, all members of the population will be evaluated based on the fitness that has been made, with members of the initial population randomly created. A new population will be formed from
the evolution of the parent chromosomes through an iteration called generation. The results of the
generations that have been carried out will produce offspring from the use of genetic operations such as
crossover and mutation. The newly formed population has gone through the stages of chromosome
elimination based on the best fitness values from parent and child, so the population size is constant.

[16] present a heuristic algorithm for maintenance scheduling of a system that has a set of
components. In this study, all components are assumed to have a rate of damage which increases with
the value of a constant increase factor. This paper proposed GA techniques for representing variables in a
preventive maintenance scheduling model that uses heuristic and metaheuristic optimization algorithms.

4. Research Methods
Scheduling preventive maintenance requires three sources: labour (technicians), materials (parts) and
equipment [17]. Scheduling support tools for this problem must be related to the assignment maintenance
due date and contribution of all resources and must be able to plan short term plans (weekly or monthly).
The researchers also have to consider the equipment because the company provides equipment with a
long operating period, and consequently, with limited maintenance tasks. Scheduling support tools that
meet company requirements are being developed. This Support Tool is approved in the preventive
maintenance scheduling algorithm which can be divided into three parts with specific objectives:

- Identification of the scheduling period and equipment availability
- Task Ordering
- Allocation of tasks to each technician based on defined order and equipment availability.

The task order is made by the head of the department of Maintenance in this company. All task was
set done in due date after considering the weight of each task. This company apply the cost of manpower
at the is divided into two parts, namely permanent workers and contract workers. Permanent workers are
workers who work in the field of care for one full year either in the milling season or not. While contract
workers are workers who are only assigned to carry out maintenance activities during the treatment season
before the production process begins for 5 months. For the contract and non-contract worker, the worker
has salary Rp 1.900.000 and Rp 1.300.000 per month [12].

4.1. Chromosome
Before the GA calculation is started, the initial chromosome is determined. The initial chromosome is
determined based on the maintenance task schedule as shown in Table 1. The chromosome length in TABLE I. is
35 activities which is used for fitness calculations only, but when calculating the generation, only
chromosome numbers 0 to 34 applies, so the length of the chromosome when it is input into GA
programming in Python process is 35 genes. From the result of the calculation with 50000 epoch, a
graph of fitness is obtained and shown in Figure 1.

| Table 1. Initial Maintenance Tasks Scheduling |
|-----|-----|-----|-----|-----|
| Activity | Manpower | Days | Start Date | End Date |
| 1 | 8 | 10 | 110 | 120 |
| 2 | 5 | 15 | 6 | 21 |
| 3 | 4 | 50 | 56 | 108 |
| 4 | 8 | 90 | 14 | 104 |
| 5 | 4 | 25 | 91 | 117 |
| 6 | 8 | 90 | 20 | 109 |
4.2. Fitness
The fitness value used as a reference in assessing whether a good chromosome is used as a solution to the problems in this study. In this research, the fitness solution is formulated from the desire for the absence of an excessive number of workers in one day, the balance of allocation of workers, and completion of treatment according to applicable limits. The fitness function is as follows:

- \[ \text{Fitness} = \sigma \text{Manpower}_{t1-120} + (\sum \text{Manpower}_{120-n} \times 100) \]
Based on Equation (1) the fitness function is made based on consideration of the maximum of worker that the problem in this research. Penalty is created to control the achieved the objectives of this research. Penalties in this research are shown in Table 2. The first is that there are restrictions on the number of workers in one day as many as 77 workers, so that if you exceed the number of workers who have been previously determined to be charged a penalty. The second is so that the number of workers can be balanced in one period, it is necessary to know the standard deviation of the number of workers allocated in one day in one period so that there will be a penalty if there is an imbalance. The third is about the time limit set in each year to complete the maintenance work so that if there is a job that crosses the line (119 days) it will be subject to a penalty according to the number of days. In addition, if the manpower penalty and the power manpower penalty produce the best value of 0 and the time is over the specified limit, it is necessary to use a small number (0.01) on the sum as in Equation (1) above, so that the fitness value remains in accordance with the real situation.

The last operation defined by genetic algorithms and used to manipulate chromosomes is fitness operations and fitness comparison. Fitness operations measure the quality of the resulting solution (chromosomes). This operation is specific to each problem and it actually tells what genetic algorithm to optimize. Fitness comparison is used to compare chromosomes based on their fitness. Basically, a fitness comparator tells a genetic algorithm whether it must minimize or maximize the chromosome fitness values.

Table 2. Penalty formula

| Penalty               | Formula                                           |
|-----------------------|---------------------------------------------------|
| Manpower Penalty      | IF (Total task \( t_n \) > 34) then (Total task \( t_n \) - 34) * 1), IF False (0) |
| \( \sigma \) Manpower Penalty | \( \sigma \) Manpower * 5                        |
| Time Penalty          | IF (End Date per Task > 120) then ((End Date per Task – 120) * 2), IF False (1) |

5. Results

The results of GA at 50000 epochs is the proposed schedule for the overhaul maintenance tasks as shown in Table 3 and the value of the fitness is presented in Figure 1. It is argued that greater number of generations is required to get the most optimum result, because of the large search space. However, in this study, it is only limited to 50000 iterations. After the maximum number of iteration (or MaxGen) is achieved, then the number of man power imply to the proposed solution is determined. The maximum number of man power required to complete the overhaul maintenance based on the result of the GA is 79 people and the minimum is 0 as shown in Figure 2. Theoretically, an optimum can be attained if the gap between the maximum and minimum manpower used in this scheduling is 0. But in this research,
the result is defined by result of iteration after the maximum number of iterations is achieved and not by finding the optimum solution. It can be observed from Figure 1 also that 50000 iteration is insufficient to get the highest fitness value because the fluctuation of fitness still high or dynamic.

After the iteration achieves the last evolve to get the generation in 50000 iteration, then researchers had to put the number of Manpower in that generation to imply in maintenance scheduling after GA result as suggest. Then, define the number of Manpower that company should provide for this scheduling in maximum is 79 and with minimum manpower that used in this scheduling is 0 was shown in Figure 2. Actually, the generation meets the optimum solution if the gap between the maximum and minimum manpower used in this scheduling is 0. But in this research, the result is defined by the number of iteration that to find the optimum solution. By seeing Figure 1, the researcher assumes that the solution not enough to get the highest fitness value because the fluctuate of fitness still high or dynamic.

![Figure 2. Maximum and minimum manpower](image)

The main objective of the use of GA is to find the schedule of overhaul maintenance as shown in Table 3. There are a tiny difference between Table 1 and Table 3 in term of the number of activities of maintenance tasks. The maintenance tasks in Table 1 is the initial generation of the GA and consists of 35 tasks and in Table 3 the number of tasks is 34. It is because of there is one activity in Table 1 (activity number 26) that actually valued 0. So if this activity is eliminated, the number of activities in Table 1 and Table 3 is the same.

| Activity | Start date | End date |
|----------|------------|----------|
| 1        | 2          | 12       |
| 2        | 2          | 17       |
| 3        | 2          | 52       |
| 4        | 2          | 92       |
| 5        | 95         | 120      |
| 6        | 31         | 121      |
| 7        | 2          | 92       |
| 8        | 2          | 72       |
| 9        | 2          | 52       |
| 10       | 76         | 121      |
| 11       | 2          | 37       |
| 12       | 10         | 60       |
| 13       | 30         | 120      |
| 14       | 60         | 120      |
| 15       | 2          | 46       |
As shown in Table 3, the end-date of maintenance activity is still over the allocation provided by the company is 120 days. Activity that conducts over the allocation time is activity 6, 10 and 26. These beyond the duration are influenced by the duration of each task is different. Even though the maximum number of required man power cannot reach the target, the required number of man power every month is less as well as the cost of the man power as seen in Table 4.

6. Analysis and Discussions

| Activity | Start date | End date |
|----------|------------|----------|
| 16       | 2          | 26       |
| 17       | 92         | 117      |
| 18       | 2          | 62       |
| 19       | 30         | 120      |
| 20       | 2          | 32       |
| 21       | 2          | 22       |
| 22       | 2          | 12       |
| 23       | 60         | 110      |
| 24       | 45         | 120      |
| 25       | 0          | 0        |
| 26       | 46         | 121      |
| 27       | 2          | 62       |
| 28       | 46         | 86       |
| 29       | 61         | 76       |
| 30       | 15         | 105      |
| 31       | 4          | 64       |
| 32       | 2          | 97       |
| 33       | 11         | 61       |
| 34       | 2          | 62       |

Table 4. Cost Allocation for Manpower

| Month | Maximum manpower Used per week | Manpower Cost (Rp) |
|-------|---------------------------------|--------------------|
|       | Before | After GA | Before | After GA |
| 1     | 71   | 71       | 134.900.000 | 134.900.000 |
| 2     | 77   | 76       | 146.300.000 | 144.400.000 |
| 3     | 77   | 75       | 146.300.000 | 142.500.000 |
| 4     | 77   | 79       | 146.300.000 | 150.100.000 |
| 5     | 69   | 67       | 131.100.000 | 127.300.000 |
| TOTAL |       |          | 704.900.000 | 699.200.000 |
In Table 4, the number and the cost of manpower in the existing condition and the proposed scheduled with GA is presented. In general, the required number of man power is reduced by 1 or 2 people monthly. Also, within one overhaul period, the total man power cost reduces from Rp. 704,900,000 to 699,200,000 or approximately Rp 5,700,000. The proposed scheduled is presented in Table 5.

Table 5. Proposed Daily Manpower Allocation

| Day | Man Power | Day | Man Power | Day | Man Power |
|-----|-----------|-----|-----------|-----|-----------|
| 1   | 0         | 41  | 70        | 81  | 76        |
| 2   | 0         | 42  | 70        | 82  | 79        |
| 3   | 65        | 43  | 70        | 83  | 79        |
| 4   | 65        | 44  | 70        | 84  | 79        |
| 5   | 65        | 45  | 70        | 85  | 79        |
| 6   | 65        | 46  | 67        | 86  | 79        |
| 7   | 65        | 47  | 75        | 87  | 79        |
| 8   | 65        | 48  | 75        | 88  | 79        |
| 9   | 65        | 49  | 75        | 89  | 79        |
| 10  | 65        | 50  | 75        | 90  | 79        |
| 11  | 71        | 51  | 75        | 91  | 79        |
| 12  | 67        | 52  | 68        | 92  | 57        |
| 13  | 67        | 53  | 68        | 93  | 63        |
| 14  | 67        | 54  | 68        | 94  | 63        |
| 15  | 67        | 55  | 68        | 95  | 63        |
| 16  | 70        | 56  | 68        | 96  | 67        |
| 17  | 65        | 57  | 68        | 97  | 67        |
| 18  | 65        | 58  | 68        | 98  | 67        |
| 19  | 65        | 59  | 68        | 99  | 67        |
| 20  | 65        | 60  | 62        | 100 | 67        |
| 21  | 65        | 61  | 64        | 101 | 67        |
| 22  | 63        | 62  | 68        | 102 | 65        |
| 23  | 63        | 63  | 68        | 103 | 65        |
| 24  | 63        | 64  | 68        | 104 | 65        |
| 25  | 63        | 65  | 68        | 105 | 65        |
| 26  | 67        | 66  | 68        | 106 | 65        |
| 27  | 67        | 67  | 68        | 107 | 65        |
| 28  | 67        | 68  | 68        | 108 | 65        |
| 29  | 67        | 69  | 68        | 109 | 65        |
| 30  | 64        | 70  | 68        | 110 | 65        |
| 31  | 70        | 71  | 68        | 111 | 65        |
| 32  | 76        | 72  | 71        | 112 | 65        |
| 33  | 76        | 73  | 71        | 113 | 65        |
| 34  | 76        | 74  | 71        | 114 | 65        |
| 35  | 76        | 75  | 71        | 115 | 65        |
| 36  | 76        | 76  | 71        | 116 | 65        |
7. Conclusion
In this paper, a schedule for an overhaul maintenance project is observed and proposed. The result shows that the proposed schedule generate less man power cost compared to the existing situation. It is concluded that the model is able to serve its purpose to improve the performance of the maintenance department. However, the result attained from the maximum number of generations is identified as not the most optimum result, because there is gap between the maximum and minimum number of required manpower.

So, it is suggested that to find the optimum solution, more iteration should be run. Also, for the further research, it is suggested to consider using Artificial Neural Network (ANN) in the process of generating the initial population of the GA in this kind of case study. It is argued that the use of ANN is capable to reduce the number of required iterations to find the optimum solution. Another research direction arose from this study is to be a mathematical model to calculate the total cost of the selected policy. The model may consist of the cost for recruitment and lay off since those cost component is neglected in this research.

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