Analysis of replacement and selection of machines using dynamic program and AHP methods

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Abstract. CV. Do’a Sepuh is a rice mill company. This factory often experiences problems in the cost of engine maintenance which increases every year. Therefore, planning actions must be taken in the form of replacement and selection of new, more economical machines. This study aims to make a model of engine replacement decisions to minimize the expectation of total costs, calculate the time (years) that is appropriate to make changes using the Dynamic Programming method. As well as making decisions on the use of new machines using the Analytical Hierarchy Process (AHP) method. Previously, a Focus Group Discussion I (FGD I) was conducted to determine which machines would be chosen and determine the engine selection criteria. Furthermore, Focus Group Discussion II (FGD II) was carried out to calculate the operating costs of new machines, revenue for new machines, the remaining number of new machines, and filling out questionnaires. The results obtained were the decision to replace diesel engines in the first year. The engine chosen, for the selected diesel engine is machine 1 (Yanmar TS 230 R).

1. Introduction
Rice milling technology is very influential in determining the quality of rice produced. In addition to mechanical factors, there are several factors that can cause the quality of rice, whether or not the grinding results are of good quality. Such as rice varieties, fertilization, temperature, method of drying and moisture content of milled grain [1]. The low quality of milled rice is influenced by several things, namely: the condition of damaged milled rice varieties, the geometric shape of rice, the level of hardness, the quality of grain indicated by high water content, the degree of purity of rice (the presence of physical contamination of rice to be milled), rice cracks in it, milling technology used, milling systems and grinding procedures [2].To produce a quality product, the engine operating conditions must be maintained. New management practices emphasize the importance of integrating machine preventive maintenance plans and product quality assurance with the aim of ensuring defect-free operations [3]. This trend has led to the development of a joint optimization model of machine maintenance and product quality control [4].

Maintenance and engine replacement plans taking into account the costs to be incurred. In this study, the engine replaced was a diesel engine, because the age of the engine was considered old that is 5 years. And to consider the proposed new engine decision to be used at CV Do'a Sepuh, the Analytical Hierarchy Process (AHP) method, the Analytical Hierarchy Process (AHP) is a decision support model developed by Thomas L. Saaty. This decision support model will outline multi-factor problems or complex multi criteria into a hierarchy, according to [5].
This study aims to model engine replacement decisions in a limited operation plan interval to minimize the expectation of total costs, and calculate the time (year) that is right for making engine changes until a balance is reached between the old equipment maintenance costs and maintenance costs for new equipment using dynamic programming methods and decision making on the use of new machines using the Analytical Hierarchy Process (AHP) method.

1.1 Rice mill
Rice mills are the central agro point of the rice industry, because this is where the main products are obtained in the form of rice and raw materials for further processing of food and industrial products [6]. Handling of post-harvest rice includes all treatment and processing activities which include the process of cutting, threshing, transporting, maintenance, drying, storing, milling, packaging, storing, and processing [7]. To obtain pure white rice, it must reach 100% social level and require a longer pulverization time. On rice milling machines, when milling, the rice rubs or is scraped so that the rice comes out through the sieve and the rice is squeezed and goes out because of the push from the next rice [1].

1.2 Dynamic programming
This deterministic dynamic programming can be explained by the following diagram:
Thus, at stage n, the process will be in state $S_n$. In this state an $x_n$ decision is made, then the process moves to $S_{n+1}$ on stage $(n + 1)$. From this point forward, the value of the objective function for the optimum decision has already been calculated, namely $f_{n+1}(S_{n+1})$. The decision to choose $x_n$ also contributes to the objective function, which by combining these two quantities will get the objective function value $f_n(S_n, x_n)$ which starts at stage n. Minimize this value by paying attention to $x_n$ so that it gets $f_n(S_n) = f_n(S_n, x_n)$. After this is done for all possible $S_n$ values, the settlement procedure moves back to the problem with one stage. A way to categorize this deterministic dynamic program problem is to look at the shape of the objective function. The other way of categorizing is based on the state of the set (state) at a stage. That is, whether state $S_n$ can be represented as a discrete or continuous state variable, or a vector state may be needed (more than one variable) [8].

1.3 Analytical hierarchy process (AHP)
AHP is a decision support model developed by Thomas L. Saaty. This decision support model will describe multi-factor problems or complex multi criteria into a hierarchy, according to Saaty [6], hierarchy is defined as a representation of a complex problem in a multi-level structure where the first level is a goal, followed by a factor level, criteria, sub criteria, and so on down to the last level of the alternative. With hierarchy, a complex problem can be broken down into groups which are then organized into a Hierarchical form so that the problem will appear more structured and systematic.

1.4 Literature review
In previous studies Yurdakul [9] proposed a model linking the machine alternatives to manufacturing strategies for machine tool selection. The evaluation of machine tool alternatives is solved considering strategic implications of the machine tool selection decision using AHP and analytic network process (ANP) methods. Ayağ and Özdemir [10] proposed a fuzzy AHP based approach to evaluate the alternative machine tools. Cost-benefit analysis is carried out using both the fuzzy AHP score and procurement cost for each alternative, and computer software is developed to make all calculations of the fuzzy AHP easier and quicker while incorporating a data-driven user interface and related database. Rubayet and Karmaker [11], the anticipated methods in this research consist of two steps at its core. In the first step, the criteria of the existing problem are inspected and identified and then the weights of the sector and sub-sector are determined that have come to light by using AHP. In the second step, eligible alternatives are ranked by using TOPSIS.

In this study the selection of machines used the AHP method with 4 Criteria and 8 Sub Criteria. The first stage is FGD I to determine which machines will be selected and determination of Criteria for
engine selection. Furthermore, Focus Group Discussion II (FGD II) was carried out to calculate the cost of operating new machines, revenue for new machines, and the remaining new machines. For the Cost Analysis criteria, quantitative methods are used. Then fill out the questionnaire.

2. Method
The method used in this study is the Dynamic Program model and Analytical Hierarchy Process (AHP) method. Dynamic programs are used for making engine replacement decisions on a limited operating plan interval. The goal is to minimize the expectation of total costs, and calculate the time (year) that is right in making engine changes. This is done to achieve a balance between the cost of maintaining old equipment and the cost of maintaining new equipment. While the AHP method is used for decision making for the selection of new machines.

Stage I: Before the AHP is carried out, the machine operating costs, machine income, engine residual value, employee salaries, and dynamic programming calculations are calculated first. Stage II: Furthermore, Focus Group Discussion I (FGD I) was carried out to determine what machines to choose and determine engine selection criteria. Stage III: Focus Group Discussion II (FGD II) was conducted to calculate the cost of operating a new engine, new engine income, and the value of the remaining new machines. Stage IV: Fill out the questionnaire. The ones assessed / selected in the questionnaire consisted of 4 criteria based on the results of the literature study and interviews with experts.

3. Results and Discussion
3.1 Machine operating costs
The operating cost of a diesel engine in year 0 is IDR 17,980,000.

| Year | Operating Cost (IDR) |
|------|----------------------|
| 0    | 17,980,000           |
| 1    | 20,677,000           |
| 2    | 23,778,550           |
| 3    | 28,534,260           |
| 4    | 34,241,112           |
| 5    | 42,801,390           |
| 6    | 52,645,710           |
| 7    | 68,439,423           |

Description: The operating costs of diesel engines have increased by 15-30% per year.

3.2 Dynamic programming (tool replacement)

| Age(t) (year) | Income (IDR) | Operating Cost (IDR) | Residual Value (IDR) |
|---------------|--------------|----------------------|----------------------|
| 0             | 4,205,053    | 17,980,000           | 16,000,000           |
| 1             | 44,284,548   | 18,879,000           | 12,500,000           |
| 2             | 39,856,093   | 19,822,950           | 9,500,000            |
| 3             | 35,870,484   | 21,805,245           | 7,000,000            |
| 4             | 32,283,436   | 26,166,294           | 5,000,000            |
| 5             | 29,055,092   | 32,707,868           | 3,500,000            |
| 6             | 26,149,583   | 40,230,677           | 2,500,000            |
| 7             | 23,534,624   | 52,299,880           |                     |
| 8             | 21,181,162   | 67,989,844           | 2,000,000            |
The picture above represents our problem. At the beginning of the first year we had equipment that was 5 years old. We can replace it (R = replace) or maintain it (K = keep). At the beginning of the second year if the equipment is replaced then our equipment is 1 year old while if the equipment is maintained our equipment is 6 years old. We can see the same thing at the beginning of the third year until the fifth year. If the equipment which is 1 year old at the beginning of the second and third year is replaced, the replacement will be 1 year old the following year. At the beginning of the fifth year the 8 year old engine must be replaced. The network shows that at the beginning of the second year the possible age of the equipment is 1 and 6 years, for the beginning of the third year is 1, 2, and 7 years, and for the beginning of the fourth year is 1, 2, 3 and 8 years.

The completion of the network is equivalent to finding the longest route from the beginning of the first year to the end of the fourth year. The calculation is shown in table 3.

| Table 3. Calculation of Stage 4 (For Decision Making) |
|-----------------------------------------------|
| t   | K       | R       | Optimal Settlement |
|     | r(t)+s(t+1)-C(t) (IDR) | r(0)+s(t)+S(1)-C(0)-I (IDR) | f4(t) (IDR) | Decision |
| 1   | 37,905,548 | 33,225,053 | 37,905,548 | K         |
| 2   | 29,533,143 | 29,725,053 | 29,725,053 | R         |
| 3   | 21,065,239 | 26,725,053 | 26,725,053 | R         |
| 8   | must be replaced | 19,225,053 | 19,225,053 | R         |

| Table 4. Calculation of Stage 3 (For Decision Making) |
|-----------------------------------------------|
| t   | K       | R       | Optimal Settlement |
|     | r(t)+s(t+1)-C(t)+f4(t+1) (IDR) | r(0)+s(t)+S(1)-C(0)+I+f4(t+1) (IDR) | f3(t) (IDR) | Decision |
| 1   | 55,130,601 | 46,950,107 | 55,130,601 | K         |
| 2   | 46,758,197 | 43,950,107 | 46,758,197 | K         |
| 7   | (Rp9,540,202) | 22,950,107 | 22,950,107 | R         |

| Table 5. Calculation of Stage 2 (For Decision Making) |
|-----------------------------------------------|
| t   | K       | R       | Optimal Settlement |
|     | r(t)+s(t+1)-C(t)+f3(t+1) (IDR) | r(0)+s(t)+S(1)-C(0)+I+f3(t+1) (IDR) | f2(t) (IDR) | Decision |
| 1   | 72,163,745 | 63,983,250 | 72,163,745 | K         |
| 6   | 29,067,248 | 27,675,160 | 29,067,248 | R         |
Table 6. Calculation of Stage 1 (For Decision Making)

| t | R | Optimal Settlement |
|---|---|-------------------|
| 5 | 25,414,473 | 35,292,302 |

Thus the optimal decision of the problem above is that for the first year the engine is replaced then for the second year the engine is maintained and for the third year the engine is maintained and for the fourth year the engine must be replaced. And the optimal absorption is IDR 214,297,209.

3.3 Focus group discussion I
In the focus group discussion I, researchers together with company owners and employees discussed the engine selection plan for diesel engines to get the machines seen in Table 7.

Table 7. Type of Diesel Engine

| No | Type          | Price (IDR)   |
|----|---------------|---------------|
| 1  | Yanmar TF 300 H | 35,828,000    |
| 2  | Yanmar TS 230 R | 27,472,000    |
| 3  | Kubota RD 140 DI-2T | 20,925,000   |
| 4  | Dongfeng S1135 M | 11,050,000    |
| 5  | Dongfeng R175 A  | 3,350,000     |

Of the five types of diesel engines, only 3 engines were selected by considering the new engine prices, and engine specifications from the manual book. So that you get 3 types of diesel engines, namely: Yanmar TF 230 R, Kubota RD 140 DI-2T, and Dongfeng S1135M. The engine criteria chosen to determine engine selection are determined based on the manual book of the engine. The other additional criteria are determined based on the results of interviews with shop owners, employees, and company owners.

- Criteria based on the manual book.
  1. **Power.** It is the power produced by the engine as the driving force or power needed by the engine to carry out the production process, engine strength or engine durability to increase engine life, engine reliability in the production process. X1.1 = The volume of Centimeter Cubic (CC) from the machine. X1.2 = Engine resistance to heating
  2. **Cost Analysis.** Calculate the costs incurred by the machine. This cost analysis is calculated quantitatively by researchers to help the company management in choosing a machine. The calculated cost analysis is:
     - X2.1 = Machine production costs. X2.2 = Machine residual value.
     - The results of this calculation are then taken to FGD II.

- Because the machine is based on the results of the interview
  3. **Maintenance.** Maintenance activities are carried out to maintain or repair company equipment in order to be able to carry out production effectively and efficiently in accordance with planned orders with quality product results. Less attention is given to maintenance due to the large amount of funds needed, and the complexity of the tasks Maintenance (maintenance) But for company operations, maintenance has become a dual function, namely the implementation and awareness to carry out maintenance of production facilities. X3.1 = ease of service. X3.2 = ease in obtaining spare parts.
  4. **Readiness.** The readiness criteria are intended to see how the company's readiness for the use of new machines will be selected.
     - X4.1 = The readiness of the company against the price of a new machine. X4.2 = Readiness of employees to adapt to new engine technology.
3.3 Focus group discussion II

Table 8. Diesel Engine Cost Analysis

| No | Machine Name       | Price    | Production Costs | Residual Value Of the Machine |
|----|--------------------|----------|------------------|--------------------------------|
| 1  | Yanmar TS 230 R    | Rp. 27.472.000 | Rp. 19.460.000  | Rp. 5.000.000                 |
| 2  | Kubota RD 140 DI-2T| Rp. 20.925.000 | Rp. 15.428.000  | Rp. 3.000.000                 |
| 3  | Dongfeng S1135 M   | Rp. 11.050.000 | Rp. 11.796.000  | Rp. 2.000.000                 |

The cost of production in Table 8 is calculated based on the energy needed by the diesel engine, calculating the cost of engine maintenance, and for calculating the residual value of the machine determined based on the predicted results of interviews with employees and company owners. Then the questionnaire was filled in to the 2 person correspondents, namely the owner and employee. Specifically Criteria number 2 (Cost Analysis) is assisted by researchers to calculate it. This was chosen based on quantitative calculations.

3.4 Results of weight of the overall hierarchy of diesel engine

![Figure 2. Results of Respondent 1](image)

![Figure 3. Result of Respondent 2](image)

3.5 Weighting results of diesel engine criteria

Table 9. Weight Results of Diesel Engine Criteria

| Alternatif | Weight | Weight | Total Weight |
|------------|--------|--------|--------------|
|            | Respondent 1 | Respondent 2 |               |
| Machine 1  | 0,379   | 0,399  | 0,778        |
| Machine 2  | 0,248   | 0,289  | 0,537        |
| Machine 3  | 0,372   | 0,311  | 0,683        |

From the results of the above data processing for the selection of diesel engines the results of the Total Weight of both weighting of the largest respondents from the assessment of the engine to increase production are selected by machine 1 (Yanmar TS 230 R) weighting 0.778.

4. Conclusion

Four criteria were obtained in the selection of machines, namely criteria: Power, Cost Analysis, Maintenance, and Readiness. From each of these Criteria each has 2 Sub Criteria. So there are 8 Sub Criteria, namely: the volume of the engine volume, engine durability to heating, engine production costs, engine residual value, ease of service, ease of obtaining parts, company readiness for new engine prices, and employee readiness for new engine technology adaptation.
The optimal decision of the problem above is that for the first year the engine is replaced then for the second year the engine is maintained and for the third year the engine is maintained and for the fourth year the engine must be replaced. And the optimal absorption is IDR 214,297,209.

AHP processing with Expert Choice 11 for the engine selection strategy shows the largest number of weighting of the two respondents to increase production, namely diesel engine 1 (Yanmar TS 230 R) weighing 0.778.

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