A Combined AHP-GP for Maintenance Project Selection in Coal Power Plant

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Abstract—A proper maintenance project selection is a key to support performance of power plant. The issue of maintenance is allocation a limited budget to achieve the goals of various maintenance criteria and conflicting objectives. This paper presents an integrated AHP and goal programming. In the first step, since maintenance is measured in qualitative criteria, it is recommended to use AHP to weight and quantify criteria. Second step utilize GP which uses the criteria weights and alternative priorities calculated with AHP to optimize multiple objectives without exceeding available resource constraint. The results show that the approach can aid in selection optimal projects within available budget.

Keywords—Analytic Hierarchy Process, Goal Programming, Performance, Project Selection.

I. INTRODUCTION

The growth of electricity generation in Indonesia is increasing at this time. This is to meet the National electrification program and meet customer growth. In the last 5 years (2012-2016) PLN’s electricity sales have increased an average of 6.7% per year [1].

PT XYZ is a company that provides operation and maintenance (O&M) services for power plants. The management of power plants has a target to achieve key maintenance (O&M) services for power plants. The issue of maintenance and upgrade spending, unit aging, plant duty or cycling, availability incentive, and individual unit performance. Its important that operation and maintenance company achieve the performance indicator in power generating unit by maintain the equipment performance. Some project improvement and rehabilitation on the equipment is needed because of ageing or plant duty cycle. Proper maintenance of plant equipment can significantly reduce the overall operating cost and increase productivity [5].

In literature, there are so many research project utilize AHP – GP approach in wide application. Study by Ciptomulyono (2000) [6], in such situations the project selection process will relate to the multi-criteria and multi-objective decision problems with quantitative and qualitative criteria which are difficult to measure, as well as project objectives in financial and non-financial terms. Therefore an integral decision model is needed that can accommodate multi-criteria and multi-objective decision problems. Multi Criteria Decision Making (MCDM) model based on Analytic Hierarchy Process (AHP) and Multiobjective Decision Making Model (MODM) in the form of 0-1 Goal Programming is integrated into a decision model for project evaluation / selection as well as optimizing the resources of the project. Bertolini and Bevilacqua [5] applied the combined AHP - GP approach to define the best strategies for the maintenance of critical centrifugal pumps in an oil refinery. AHP approach to identified priority levels for the different maintenance policies with respect to the FMECA criteria and the GP method used to identify the best set of maintenance type for the equipment failure modes considered. Ho [7] applied the combined AHP - GP approach to design the logistics distribution network for selecting the best set of warehouses without exceeding the limited available resources. Rusli and Ciptomulyono [8] applied the combined AHP – GP approach to select the contractors for turbine rotor repair of power plant with criteria and subject to available budget. Badri [9] applied AHP – GP approach to help selecting the best set of quality control instruments for customer data collection purpose which AHP approach to weighting of service quality criteria and utilize GP approach to select optimal service quality control instruments with respect to resource limitation (i.e., budget, manhour, labor).

II. METHOD

A. AHP

The Analytic Hierarchy Process (AHP) provides the objective mathematics to process the inescapably subjective and personal preferences of an individual or a group in making a decision. Fundamentally, the AHP works by developing priorities for alternatives [10]. AHP is applied to support many types of multi-criteria decision problems. It has particular application in group decision-making, and it has recently become increasingly popular around the world in a
wide variety of decision situations, in fields such as public policy, business, industry, healthcare, shipbuilding and education. This method helps people to set priorities between alternatives, sub-criteria and criteria in the decision-making process. Also, it helps making better decisions by taking into account the qualitative and quantitative aspects of the decision [11].

AHP application steps are as follows [6,11]:

Step 1: Determine the problem, determined goal and develop model in structure hierarchy, determine criteria and alternatives. This step contains aim of decision-maker and strutured hierarchical of goal, criteria and alternatives. Structure the decision hierarchy from top with goal, intermediate level of criteria, and lowest level set of alternatives (Fig.3 a).

Step 2: Make pairwise comparisons of criteria and comparisons of alternatives for each criterion. Make a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it. The pairwise comparison is conducted by doing survey to decision maker expert which is more important by making comparison according to 1-9 scale as shown in Table 2.

Step 3: Calculation of priority vector. By using the comparison matrixes, the vector of weights (w) is computed in two steps. First, the pairwise comparison matrix, then the weights are computed.

Step 4: Calculate and check the consistency ratio (CR). In the AHP, the pairwise comparisons in a judgement matrix are considered to be adequately consistent, if the corresponding CR is less than 10%. The CR coefficient is calculated after Consistency Index (CI). CI is defined and numerical calculation is made as follows:

\[
(CI) = (\lambda_{\text{max}} - n)/(n - 1) \tag{1}
\]

Next the CR is obtained by dividing the CI value by the Random Consistency Index (RCI). RCI values are shown in Table 2. Then, the CR value is calculated by using the formula:

\[
(CI) = CI/R \tag{2}
\]

The test of consistency is completed when the CR is numerically calculated. If CR < 10%, achieved data is consistent If CR>10%, achieved data is inconsistent, the original values in the pairwise comparison matrix should be reconsidered and revised.

Step 5: Analysis of the AHP scores. After all 4 steps, if the model is consistent, the best alternative by AHP score is chosen. The fundamental scale can see Table 1 [10].

1) AHP Group Decision

According Saaty there are two ways to generate entries: (1) consensus vote and (2) individual judgements. By using individual judgement and check the consistency ratio in each participant. If result > 10% then use revise the answer [10]. The survey was conducted on seven experts consisting of 2 managers, 3 assistant managers, and 3 engineers.

The individual’s judgment with CR < 10% is then combined using the geometric mean for each pairwise comparison (Figure 2b). The geometric mean is an appropriate rule for combining AHP because it maintains the
reciprocal property in the pairwise pairwise comparison matrix (Figure 1c.) [10]. Combined judgment
\[ a_{12} = [a_{12}^1 a_{12}^2 x \cdots x a_{12}^N]^{1/N} \] (3)

B. Goal Programming

The Goal Programming model is used to solve problems more broadly than other approaches to solving multi-objective problems. Previous research, Ciptomulyono (2000) [6] stated that the advantage of goal programming is that this method contains fewer aspects of subjectivity compared to other multicriteria methods such as the Utility Theory Method or ELECTRE and has more effective procedures in weighting. The weakness of the goal programming method is that it does not have a systematic method of weighting, setting aspirations of goals and normalizing variable deviations. Goal programming is not able to overcome the selection of decisions if there are qualitative criteria. To improve these two deficiencies, it is proposed to use the AHP method. The integration of AHP and Goal Programming can complement the shortcomings of each method. The combined AHP-GP development model step shown in Figure 2. Steps in Goal Programming [6]:

1. Formulate a mathematical model consisting of objective functions, goal constraints. Because the decision process is accepting and rejecting, the model is Zero One Goal Programming (ZOGP).
2. Determine the qualitative decision attributes of the AHP process to be transformed into a decision variable and an objective function parameter.
3. Conduct analysis and test of model sensibility that enables obtaining an adequate level of validation.

The form of transforming the constraint/goal function into an equation in Goal Programming can be formulated as Table 2.

III. RESULT AND DISCUSSION

Input data from AHP in this study from group decisions for criteria and alternative maintenance projects are shown in
Table 3 shows the Superdecisions result on calculation relative priority each alternatives decision towards criteria. Researchers use an inconsistency ratio of 0.10 or less as guidelines in evaluating consistencies [12].

The power plant XYZ consist of two unit no. 1 and unit no. 2 and common system facilities. The description of projects improvement and upgrade will be planning in area as follow: project boiler refractory rehabilitation (x1) for 2 units, project line cooling replacement (x2) for common system, project valves replacement (x3) for valve in turbine and boiler area in 2 units, project houseload modification (x4) for 2 units, and project air preheater tubes replacement for 2 units.

Table 4 show the result of weights of alternative comparison for each performance indicator criteria in aggregate group decision. Inconsistency ratio is accepted ≤ 0.1.

Table 5 show the result is an overall prioritization of the performance indicator decision criteria of aggregate grup decision with inconsistency ratio ≤ 0.1. The results of this step are the overall rankings (in terms of weights) of the five maintenance projects candidate preference. From AHP result will be combined in GP as step shown in Fig. 3. Table 6 show the result overall weights or projects (alternatives).

### A. Formulation of Goal Programming

Goal programming formulation determine function: decision variable, priority, goal constraint and goal function. Table 6 show estimation budgetary limitation as use for resource constrain.

1) **Decision Variable**

\[ x_i = \text{decision variable for select project } i \]

1. \( i = 1, 2, 3, m \)
2. \( 0 \leq x_i \leq 1 \)

2) **System constraint**

Priority 1: Prevent repeated select same project

\[ X_i \leq 1 \text{ (for } i = 1, 2, \ldots, 5 \) \]

Priority 2: At least select three projects

\[ x_1 + x_2 + x_3 + x_4 + x_5 \leq 3 \]
3) **Resource constraint**

Priority 3: Keep cost within the budget Rp. 20 M. Table 7 show estimated cost for maintenance project. Resource constraint will be use as goal constraint to know the effect on this model.

\[
2.8x_1 + 9.5x_2 + 4.2x_3 + 7.6x_4 + 3.2x_5 + n_C - p_C \leq 20
\]  

(6)

4) **Goal constraints**

Goal constrain is needed to ensure that maintenance project with the highest weight obtained from AHP analysis will be selected in Table 5. Such goal constrain will attempt to maximize the weights by selecting the manitenance project with high priority.

0.297x_1 + 0.185x_2 + 0.219x_3 + 0.158x_4 + 0.141x_5 + n_P - p_P = 1 \nonumber  

(7)

Maximize project that have highest score for each criteria weights. Righ hand side is sum of three highest scores of project alternative from Table 3 (i.e the most project give useful contribution to achive EAF). The ordering goal constraint according criteria weights result from AHP process: Safety (0.539), Availability (0.221), Reliability (0.140), Efficiency (0.100).

Maximize Safety:

0.289x_1 + 0.194x_2 + 0.300x_3 + 0.110x_4 + 0.107x_5 + n_1 - p_1 = 0.783 \nonumber  

(8)

Maximize Availability:

0.345x_1 + 0.194x_2 + 0.073x_3 + 0.252x_4 + 0.136x_5 + n_2 - p_2 = 0.791 \nonumber  

(9)

Maximize Reliability:

0.403x_1 + 0.163x_2 + 0.069x_3 + 0.239x_4 + 0.126x_5 + n_3 - p_3 = 0.805 \nonumber  

(10)

Maximize Efficiency:

0.088x_1 + 0.148x_2 + 0.313x_3 + 0.097x_4 + 0.354x_5 + n_4 - p_4 = 0.815 \nonumber  

(11)

\[ \text{and } x_i = 0 \text{ or } 1; n_k, p_k \geq 0 \]

The objective function to minimize the overall deviation in each of the goal constraints.

\[
\min Z = P_1(p_C) + P_2(n_P + p_P) + P_3(0.539n_1 + 0.221n_2 + 0.140n_3 + 0.100n_4)
\]  

(12)

B. **Solution of the goal programming**

The goal programming model was solved using LINGO [14], Figure 3. LINGO (Linear, Integer, Nonlinear, and Global Optimization) is a mathematical modelling language designed particularly for formulating and solving a wide variety of optimization problems, including linear programming, nonlinear programming, and integer programming.

**IV. RESULT AND DISCUSSION**

Table 8 present the result from goal programming for project selection are boiler refractory rehabilitation (x_1), valves replacement (x_3), houseold modification (x_4), and air preheater tubes replacement (x_5). The budget goal constraint can be achieved and 3 target performance indicators priority (safety, availability, reliability) can be achieved except for
efficiency is under achievement. The project line cooling water replacement were not selected because limitation value by system constraint, goal constraint, and priority. The result of this model can be proposed to management to support the decision making of selecting equipment maintenance project in power plant XYZ.

A. Sensitivity Analysis

Sensitivity analysis used to know the effect of increasing and increasing resource constraint budget in this model from -20%, -10%, and +10%, and 20%. The results show in table 9 project selection and no of project change with variance of available budget. Goal constraint keep cost bellow available budget, with lowering budget has effect -10% to -20% on fewer project to be chosen and change project to its optimal solution. Sensitivity analysis can be used to analyze the effect of constraint or goal target to the model and result. This analysis can help management or maintenance planner to select project for optimal result based on available budget.

V. CONCLUSION

This paper proposes combined AHP and goal programming to the selection of maintenance project for equipment in power plant XYZ. The approach can handle the multiple and conflicting goal and constraints characteristic such as performance indicator criteria, budget constraints, and system constraint. This AHP-GP model consist of two stages: first stage using the AHP to find weights of criteria and alternatives and second stage find optimal problem solving by goal programming for selecting maintenance project. These model can be studied further for adding resource constraint such as management work hour, labor work hour, and project duration.

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