

Development of a Conceptual Framework to Determine Improvement of IT Governance Using COBIT 5 and AHP-GA

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Abstract—The management information and technology are used as a structure and control in the synchronization of IT's function and business goals. Researchers are doing evaluation of the IT's management in PT PLN Kediri Area using COBIT 5 framework on APO08, BAI02, and BAI07 domains to get the recommendation of improvements to achieve the company's goals. In the process of selecting improvement recommendations that produced by the evaluation of IT's management using COBIT 5 Framework in PLN Kediri, there are obstacles found in determining the selection priority of the improvement recommendations in the evaluated domain. This paper suggests a framework which combines COBIT 5 frameworks in the evaluation of IT's management, and implement the Analytical Hierarchy Process (AHP) and Genetic Algorithm as a solution to solve the problem in the selection of improvement recommendations in each domain. The contribution in this study is a new framework that can be used to evaluate IT's management and determine the improvement recommendations. There has been no research related to the framework that used COBIT 5 and AHP-GA in evaluating IT's management and determining the priority of improvement recommendations.

Index Terms—COBIT 5; AHP; GA; Framework.

I. INTRODUCTION

Information systems and its technology get a very important position in companies to perform a variety of businesses in the development and the implementation of information technology to support the activities. This effort was taken to maintain the existence and the improvement of the company. IT's management itself becomes an important part to ensure that the company's information and the technology that available can support the achievement of business' goals [1][2]. To achieve those business's goals, it is required a control mechanism or an audit of information and technology that works to ensure that the application of IT has been done efficiently, to keep the integrity and security of organization's data save [3]. Audit of information and technology is the process of collecting and evaluating all the information system activities in the company [4]. There are standards that can be used and recognized internationally when performing the information systems of audit's management. One of the standards used was COBIT 5 (Control Objectives for Information and related Technology) issued by the IT Governance Institute, which is part of ISACA [5].

In the previous research, COBIT 4.1 was explored to discover the effectiveness level of the process by putting the conceptual model of COBIT 4.1 to the relevant audit evaluation. This study used AHP to determine domain in each

process of PO and AI. The measurements were made using the COBIT standard by determining the maturity level in each of the selected domain [6]. The application of AHP to determine the domain of COBIT 4.1 was also applied in the previous study on PT Nikkatsu Electric Works using the whole domain of COBIT 4.1 with PO, AI, DS, and MEA [7]. This study discussed about the tools that are used to communicate between client-vendor to support multiple functions of IT control which are regulated by the COBIT framework. The domains in COBIT framework also used to map the communication and control in project development [8]. COBIT and ISO 27001 are also applied to evaluate the information technology security at the insurance company. The result of this study was to highlight the importance of data security evaluation in an insurance company as the customer's data are confidential and important [9].

In a previous study, the authors used the standard of COBIT 5 framework in auditing information and technology's management in PT PLN Kediri. The study was conducted to discover how far the information and technology's management that has been run in APO domain, APO08 subdomain, BAI domain, BAI02 and BAI07 subdomain. Based on the mapping of COBIT 5 Enterprise Goals to IT-related Goals, it three domains was obtained in the process. There are APO08 (Manage Relationship), BAI02 (Manage requirements definition.) and BAI07 (Manage change acceptance and Transitioning) [10]. The results of the study were recommendations in managing information and technology. In the application of improvement recommendations produced in evaluating the IT's management using COBIT 5 Framework 5 in PLN Kediri, there are obstacles found in determining the priority of the selection of improvement recommendations in the evaluated domain. In the process of determining the ranking of improvements recommendations in each domain of COBIT 5, there are determination process for the criteria quality and alternatively, Analytical Hierarchy Process (AHP) can be used as a solution to resolve this problem [11].

Combination of the AHP and the Genetic Algorithm has been applied as a solution to resolve the problem in determining improvement recommendations [12][13]. By using the genetic algorithm to optimize the quality of criteria and AHP to calculate the alternative quality value to get the best recommendation, the combined method of AHP and GA in this study is proven capable to produce better solutions.

Based on the background description, the researchers suggest a framework which combined COBIT 5 framework in the evaluation of IT's management and applying the AHP

and the GA as a solution to resolve the problem in the selection of improvement recommendations in each domain. The AHP is applied using the weights of criteria and weight of alternative. The determination weights of criteria are very important to get appropriate of an alternative. The results were tested using Spearman ranking correlation by comparing the results of ranking made by the system with a ranking based on the results of expert calculations. However, as the application of the AHP produced less in accuracy, the weight of criteria optimized together with GA to overcome the problem of poor accuracy rate. The GA has improved the accuracy of the results of the ranking domain in COBIT 5 [11]. As a contribution of this paper, a new framework is proposed that can be used to evaluate IT management and determine the improvement recommendations. There has been no research related to the framework using the COBIT 5 and the AHP-GA in evaluating IT management and determining the priority of improvement recommendations.

II. RESEARCH METHOD

A. The proposed approach framework

The proposed framework that focuses on three steps is shown in Figure 1.

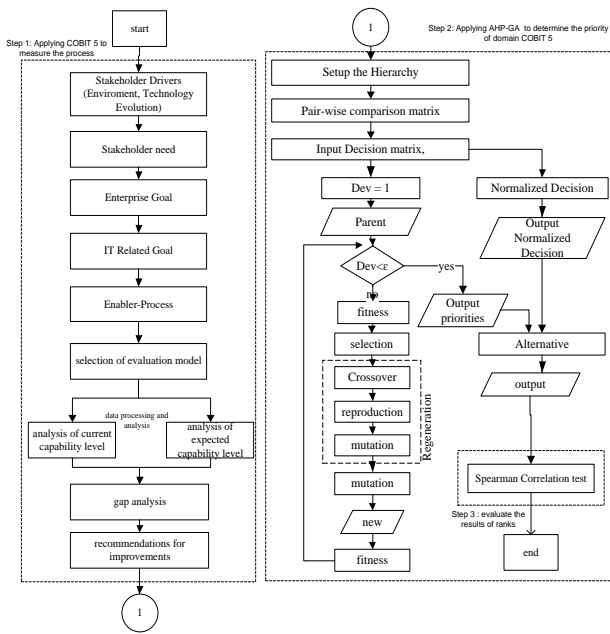


Figure 1: The proposed approach framework.

B. Step 1: Applying COBIT 5 to measure the process

COBIT is an IT governance framework and a supporting tool that allows managers to bridge the gap between control requirements, technical issues, business risks, and controls communication with stakeholders [14]. COBIT 5 is the latest generation of ISACA guidance that discusses the governance and management of IT. COBIT 5 is developed based on the past experiences who use COBIT for more than 15 years at many companies from various fields such as business, community IT, risk, insurance, and security [15] [16].

In a study [10], respondents who participated in the dissemination of the questionnaire is five employees of the IT department by RACI chart. This research uses descriptive qualitative data analysis techniques that highlight the sources of data and facts. This domain covers strategy and tactics, and

identify the best way of IT in order to contribute to the achievement of the business goals. An appropriate organizational and technological infrastructure must be put into place [14][15]. Based on the research method, it is the enterprise goals are identified and mapped into IT related field goal together with the IT process for evaluation. Table 1 shows the mapping results and the domain of APO08, BAI02, and BAI07 [10].

Table 1
The Mapping Results

Enterprise Goal	IT Related Goal	IT Process	Capability Level
Optimization of business process functionality	Enablement and support of business processes by integrating applications and technology into business processes	APO08- Manage Relationships BAI02- Manage Requirements Definition BAI07- Manage Change Acceptance and Transitioning	56% - Performed Process 50% - Performed Process 53% Performed Process

C. Step 2: Applying AHP to determine the priority of domain COBIT 5

AHP offers many advantages in explaining the decision-making process. One of them can be graphically described to make it easier to comprehend by everyone involved in the decision making [17]. The basic principles of the AHP are as follows [11]:

i. Create a hierarchy

A complex system can be understood by dividing it into several supporting elements, then compiling them into a hierarchy and combination.

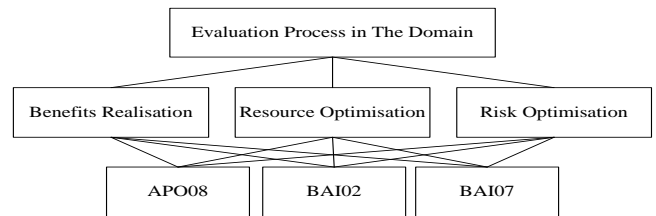


Figure 2. hierarchy structure of AHP

ii. Make the assessment criteria and alternative

The necessary criteria for selection of priority improvements in the domain COBIT 5 are as Table 2:

Table 2
The Weight Criteria

Criteria
Benefits Realization
Risk Optimization
Resource Realization

The criteria and alternatives are conducted by paired comparison. The value comparison scales can be measured using several analyses as shown in Table 3 [18][19].

Table 3
Scale Ratings Pairwise Comparisons

	Description
1	Two factors contribute equally to the objective (<i>equal</i>)
3	Experience and judgement slightly favour one over the other. (<i>moderate</i>)
5	Experience and judgement strongly favour one over the other. (<i>strong</i>)
7	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice. (<i>very strong</i>)
9	The evidence favouring one over the other is of the highest possible validity. (<i>extreme</i>)
2,4,6,8	When compromise is needed
1/(1-9)	Two factors contribute equally to the objective (<i>equal</i>)

a. *Synthesis of priority*

For each criteria and alternatives, a paired comparison should be used. Values relative proportions of the entire alternative criteria can be suited with the judgment that has been determined to produce weight and priority. Weights and priority calculated by the matrix.

b. *Logical Consistency*

Consistency has two meanings. First, similar objects can be grouped according to its relevance. Secondly, the level of relationships between objects is based on specific criteria. The steps in the method of AHP:

- i. Defining the problem and determine the desired solution, then draw up a hierarchy of the problems faced.
- ii. Determining the priority elements.
- iii. Synthesis.
- iv. Consistency.
- v. Consistency Index (CI).
- vi. Consistency Ratio (CR).
- vii. Check the consistency of the hierarchy.

At this stage, the examination of the consistency of assessment is performed. When the value of consistency deviates from the value of the best consistency, then the process assessment should be improved or repeated. The equation for calculating the consistency is shown in Equation (1) and (2) [20]:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{1}$$

$$CR = \frac{CI}{RI} \tag{2}$$

GA is the type of Evolution Algorithm that is frequently used in problem-solving. GA maps a problem into a string of chromosomes consisted of a number of genes describing variables and fitness function. GA also capable to assess how good is a chromosome to become a feasible solution [12].

D. *Step 3: Applying GA*

The third step is testing the use of Spearman Correlation by comparison AHP rankings with rankings based on calculations of experts, using the Equation (3) [12].

$$rs = 1 - \frac{6 \sum d^2}{n(n^2 - 1)} \tag{3}$$

Explanation:

- rs : Spearman Correlation
- d : the difference in ranking
- n : The number of data

III. RESULTS AND ANALYSIS

E. *Application of COBIT 5*

In this study, using a sub domain APO 08, BAI02, and BAI07 consisting of descriptions shown in Table 4.

Table 4
Domain APO08 BAI02, and BAI07

Subdomain	Base Practices (BPs)	Description
APO08	APO08-BP1	Understand business expectations.
	APO08-BP2	Identify opportunities, risks and constraints for IT to enhance the business.
	APO08-BP3	Manage business relationship.
	APO08-BP4	Coordinate and communicate.
	APO08-BP5	Provide input to the continual improvement of <i>services</i>
BAI02	BAI02-BP1	Define and maintain business functional and technical requirements.
	BAI02-BP2	Perform a feasibility study and formulate alternative solutions.
	BAI02-BP3	Manage requirements risk.
	BAI02-BP4	Obtain approval of requirements and solutions.
BAI07	BAI07-BP1	Establish an implementation plan.
	BAI07-BP2	Plan business process, system and data conversion.
	BAI07-BP3	Plan acceptance tests.
	BAI07-BP4	Establish a test environment.
	BAI07-BP5	Perform acceptance tests.
	BAI07-BP6	Promote to production and manage releases.
	BAI07-BP7	Provide early production support.
	BAI07-BP8	Perform a post-implementation review.

The term ‘current capability’ means it is the average value from the Level maturity of the actual (As Is) process of APO08, BAI02, BAI07. Meanwhile, the Expected Capability is the average value of the target level of maturity expected (To be). Table 5 shows the average results of Capability Level.

Table 5
Gap Analysis Maturity Level (Capability Level)

Domain	Current Capability	Expected Level	Gap
APO08	1	3	2
BAI02	1	3	2
BAI07	1	3	2

F. *Application of AHP*

The first step is to create a matrix of pairwise comparisons among the criteria using a rating scale of 1 to 9. The result is presented in Table 6.

Table 6
Pairwise Comparison Matrix

	BR	ReO	RiO
BR	1	2	1
ReO	0.5	1	2
RiO	1	0.5	1
Total	3.5	6.5	5.5

The next step is calculating the row averages using the Equation (4), Weight Sum Vector calculated by the Equation (5), and Consistency Vector calculated by the Equation (6). The result is presented in Table 7.

$$RA = \frac{total}{3} \tag{4}$$

$$WSV = \text{Pairwise Comparisons} \times RA \tag{5}$$

$$CV = \frac{WSV}{RA} \tag{6}$$

Description:

RA = Row Average

WSV = Weight Sum Vector

CV = Consistency Vector

Table 7
Value of Matrix

	BR	ReO	RiO	T	RA	WSV	CV
BR	0.28	0.25	0.4	0.93	0.31	0.95	3.05
Re O	0.57	0.5	0.4	1.47	0.49	1.50	3.07
Ri O	0.14	0.25	0.2	0.59	0.19	0.59	3.03

The next step is calculating the Consistency Index by calculating the value of lambda. This is done by adding up the value of consistency vector then divided by the number of criteria.

$$\lambda = \frac{(3.053+3.077+3.03)}{3} = 3.05$$

Subsequently, calculate the Consistency Index as per Equation (1).

$$Consistency\ Index = \frac{3.05 - 3}{3 - 1} = 0.026$$

The calculation of Consistency Ratio is used to ensure that the value of Consistency Ratio is less or equal to 0.1. If the value of the Consistency Ratio is higher than 0.1, then the Pairwise Comparisons should be improved. Random Index (RI) for three criteria is 0:58. The results of the calculation are as follows.

$$Consistency\ Ratio = \frac{0.026}{0.058} = 0.04$$

The next step is choosing a recommendation with three domains as an alternative. The alternative value obtained from the comparison between domains based on predetermined evaluation criteria. The process is similar as on weighted criteria. The alternative value based on each criterion are described in Table 8(a), 8(b) and 8(c).

Table 8(a)
The Weight of Alternative BR

BR	APO08	BAI02	BAI07
APO08	1	2	0.5
BAI02	0.5	1	0.333333
BAI07	2	3	1

Table 8(b)
The Weight of Alternative ReO

	APO08	BAI02	BAI07
APO08	1	0.5	2
BAI02	2	1	0.333333
BAI07	0.5	3	1

Table 8(c)
The Weight of Alternative BR

	APO08	BAI02	BAI07
APO08	1	0.333333	2
BAI02	3	1	2
BAI07	0.5	0.5	1

The final results are obtained from the assessment matrix multiplication between the values of the alternative criteria and the weights on criteria, as shown in Table 9:

Table 9
Values Alternatives Based on Criteria

	BR	REO	RIO
APO08	0.297258	0.332275	0.268013
BAI02	0.163781	0.297884	0.537374
BAI07	0.538961	0.369841	0.194613

The value of the final result is obtained by multiplying the value of each alternative with the weight value criteria (criteria averages row in Table 6) in order to obtain the ranking criteria.

Table 10
Results of Rankings

Process	Rank
APO08	0.308654
BAI02	0.303384
BAI07	0.387962

The final results obtained by calculations from beginning to end, then for recommendation improvements made in BAI07, then in APO08 and last in BAI02 as the best alternative.

Spearman Correlation calculation is used as a comparison rankings that are produced by experts for the system. Table 11 shows the results of the Spearman Correlation coefficient calculation.

Table 11
Spearman Correlation Calculation Results

DOMAIN	Rangking Pakar	Rangking Sistem	d	d ²
APO08	2	3	1	1
BAI02	3	2	2	1
BAI07	1	1	0	0
TOTAL			2	

The results of the calculations in Table 10 are used to calculate the Spearman Correlation using Equation (3), thus obtained the following results:

$$rs = 1 - \frac{6(2)}{3(3^2 - 1)} = 0,5$$

The significant of the results obtained by the Spearman Correlation is described in Table 12.

Table 12
Meaning of Value

Value	Description
0,00-0,19	Very low / very weak
0,20-0,39	Low / weak
0,40-0,59	medium
0,60-0,79	High / strong
0,80-1,00	Very high / very strong

According to Table 12, the accuracy of the results obtained and the ranking system of 0.5 belongs to the moderate level of correlation. The results of the ranking accuracy can be improved by using the AHP and using GA for the weight optimization to obtain better results.

The first step in GA is to define the representation of chromosomes (encoding). Chromosome representation is very important because it will affect all subsequent stages of the genetic algorithm [21]. In this study, a real code chromosome representation used to describe the weight of AHP. Chromosomes are formed based on the AHP scale for pairwise comparisons. The GA is chosen because it is suitable to overcome optimization problems [14].

$$[1,2,3,4,5,6,7,8,9, \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{5}, \frac{1}{6}, \frac{1}{7}, \frac{1}{8}, \frac{1}{9}]$$

The length of the gene on a chromosome is 3. The gene is the number of a matrix in AHP criteria weight comprising benefits realization, risk optimization and resource optimization. Examples of the chromosome representation are shown in Figure 4.

Position	1	2	3
Gen	0.25	0.33	3

Figure 4: Representation of Chromosomes

Chromosome included in the calculation of weight comparison matrix of AHP is shown in Table 13.

Table 13
Location of Genes on AHP

	BR	ReO	RiO
BR	1	0.333333	1
ReO	3	1	3
RiO	1	0.33	1
Total	5	1.6	5

The next step is to determine the fitness that is used to measure the chromosome [22]. The equation is used as a fitness value calculation results from the AHP and followed by the degree of correlation from Spearman Correlation in the Equation (3).

Furthermore, the cell values are divided by 12 into their respective columns in the table. The results are shown in table 14.

Table 14
Value Matrix And Total

	BR	Re O	Ri O	T	RA	WSV	CV
BR	0.2	0.2	0.2	0.6	0.2	0.6	3
Re O	0.6	0.6	0.6	1.8	0.6	1.8	3
Ri O	0.2	0.2	0.2	0.6	0.2	0.6	3

Subsequently, the multiplications between alternative value based criteria in Table 13 with the weights Criteria (row average criteria) in Table 14 are performed to get the Final Value Domain. Then the comparison between ranking generated by experts and the resulting ranking system by using the AHP weighting criteria with GA is made. Figure 5 shows the results of the ranking using the AHP-GA.

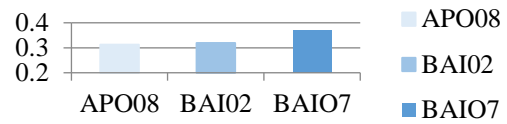


Figure 5: The value of rank

Table 15 shows the results of Spearman correlation coefficient calculation.

Table 15
The Results of Spearman Correlation

Domain	Expert	AHP-GA	d	d ²
APO08	2	2	0	0
BAI02	3	3	0	0
BAI07	1	1	0	0
TOTAL				0

The results of the calculations in Table 15 are used to calculate the Spearman Correlation using Equation (3). The results obtained are used in the formulation of the Spearman correlation levels to determine the quality of the best chromosome. The optimized weight using a genetic algorithm can improve the Spearman correlation level, so the result of the AHP ranking is near to the expert ranking using the following calculation.

$$rs = 1 - \frac{6(0)}{3(3^2 - 1)} = 1$$

The parameters of the genetic algorithm are the size of the population (popsize) is 5, crossover rate (cr) is 0.8 and mutation rate (mr) is 0.2. The initial population is formed using a random number with a predetermined range of numbers. Therefore, the parameters chromosome 5 are shown in Table 16.

Table 16
Initial Population

	Chromosome			Fitness
P1	0.25	0.33	3	0.556
P2	2	6	0.5	0.556
P3	8	5	6	0.778
P4	0.33	1	3	1
P5	0.5	7	0.5	1

Crossover is used to form a new chromosome or offspring of the cross of two chromosomes. Crossover mechanism is a one cut point crossover [23]. In this method, two chromosomes crossover will be selected randomly together with the point of intersection. The redemption limits the genes on both chromosomes to produce one offspring for each crossover process.

Parent 1	0.25	0.33	3
Parent 2	2	6	0.5
Child 1	0.25	0.33	0.5

Figure 5: The process of Crossover 1-point

Crossover process produced four offspring because it is based on the result of multiplying the value of cr (0.8) with popsize (5), which is 4 in total. The result of the crossover process is shown in Table 17.

Table 17
Results of Crossover

	Chromosome		
c1	0.25	0.33	3
c2	8	5	3
c3	0.33	1	0.5
c4	0.5	7	3

The mechanism of mutation here is done by swapping mutation. Two genes on a chromosome are selected randomly, then both genes are exchanged. The process of swapping mutation is shown in Figure 6

Parent 1	0.25	0.33	3
Child 1	3	0.33	0.25

Figure 6: Swapping Mutation

Mutation only produces one offspring as per the result of multiplying the value mr (0.2) with popsize (5). The result of the mutation process is shown in Table 18.

Table 18
The Results of Swapping Mutation

	chromosome		
c1	3	0.33	0.25

The selection process is performed using elitism methods that sort the fitness values from the largest to the smallest. The selection process is started by selecting an individual with the greatest fitness as much as the initial population size. Then, the selection is repeated until the tenth generation has in the largest fitness value as the individuals selected. The result is shown in Table 19.

Table 19
The Results of Selected Individuals

	chromosome		
c1	3	0.33	0.25

By using the weight from genetic algorithms, the correlation value is 1. According to Spearman correlation table, correlation number 1 belongs to the very high levels of correlation. The correlation value is obtained from the weighting is greater when compared with that assessment without weighting, which was 0.5. The higher level of correlation is also recorded when comparing between the ranking of experts rank with the results weighted by the genetic algorithm, which is classified as a better ranking result [12].

IV. DECISION

The framework proposed by the authors is utilizing the COBIT 5 and AHP-GA to assist the process of determining recommendations for improvements in PT PLN Kediri in getting priority ranking of improvement. The outcome of this research is to generate appropriate recommendations for improvement in a company. The company can use this framework to enhance the capability value on each domain. The rated capability of high effect is proven to increase the value of enterprise IT governance at PT. PLN Kediri.

V. CONCLUSION

The evaluation results of the information and technology management audit in PLN Kediri Area are based on a calculation of COBIT 5 capability level framework. Specifically, the APO08 subdomain (manage relationship) has a value of 56%, BAI02 (manage requirements definition) has a value of 50% and BAI07 (manage change acceptance and transitioning) has a value of 53 % and recorded at the 1st level capability. To increase the capability level's value of each domain, it needed the improvement recommendations. In this study, the researcher suggested a framework that is readily available to determine the rank in the improvement recommendations. The results of the selection of improvement's priority using the AHP-GA in the framework that can be used to increase the level in each process domain of COBIT 5. In turn, it can be used as improvement recommendations for the company. For future work, the researchers will compare the results of the audit of IT management using frameworks that have been applied in two large companies and three small companies, to further verify the framework.

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