Measuring Maturity Index of Risk Management for IT-Governance Using Fuzzy Ahp and Fuzzy Topsis

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Abstract - Increased business competition among the companies demand them to develop more. The development is not separated from the business risk and weaknesses. The business risks and weaknesses can be known and evaluated quickly using SOP (Standard Operating Procedure) which is simulated through YAWL application. Once the simulated weaknesses are identified, then it is conducted the index maturity of risk management to determine the company's understanding and concern on the existence of risks in the company's business process and risk management responsibilities within the organization itself. The method of measuring the evaluation of maturity index on risk management mostly uses measurement step by assessing and weighing the result from observation, interview, survey, etc., but if the data is not quite good then it will cause problem. Therefore, we need a new model for measuring and knowing the risk alternatives faster to be able to initiate risk-prevention. In this research, fuzzy logic model is used in making decision of the biggest risk alternative and to be handled for the first time. Fuzzy AHP will be used to calculate the value of the criteria, taken from the maturity index COBIT and Fuzzy TOPSIS to determine the selected alternative rating. It is observed that Managed and Measurable maturity index have the smallest weight of 0.0355 compared to other criteria (That means the company does not reach the level of maturity to understand risks in managed and measure) and Database Server achieves very serious attention because the score is very high compared to the other alternatives of 1.1186.

Keywords: Risk Management, Maturity Index, IT Governance, COBIT, Fuzzy AHP, Fuzzy TOPSIS.

I. INTRODUCTION

The competitive and rapidly changing business environment demands the company develop more. The development is conducted by increasing the productivity, improving the quality of business process and reducing the cost of business work. In addition, reducing company's weaknesses and business risks is also important. This step can be conducted well if the company is able to evaluate quickly the whole running process. Evaluation of running business processes can be performed by implementing Business Process Management (MPB). Business Process Management is conducted with the aim of obtaining the efficient business process for the organization.

The business process consists of a set of activities performed in the company. Usually, business process in the company is referred to as SOP (Standard Operating Procedure). This SOP will be simulated and evaluated through YAWL application software to know the running business process activity and the record will generate event log. Event log records all sequences of activity that runs from the initial to the final activity. It is made a simulation to predict the weakness of company's SOP that have the potential as a source of risk from the event log.

Risk-based IT management is very important because the successful companies are able to understand and manage the risks that may occur and threaten the information technology asset in the company.

Information technology governance has a wide scope and concentrates on the performance and transformation of information technology to achieve the company's business objectives, both internal and external business [1]. There are five 5 focus areas of IT Governance those are: Strategic alignment, Value delivery, Resource management, Risk management, and performance measurement.

Risk management is needed to be conducted to reduce losses and increase opportunities [2]. In this study, the used risk management supporter process (based on COBIT) are: AI2 (obtaining and maintaining application software), DS5 (ensuring system security), DS11 (managing data) and DS12 (managing the physical environment).

Maturity index is needed to be measured to make the management understands the level of company maturity position at the moment, and continuously tries to improve it so that the aspect of governance on company's information technology can run effectively [3].

Method of maturity index evaluation measurement on risk management has used many measurement steps by assessing and weighting the result of observation, interview, survey, etc., but if we obtain not adequately good data it will cause some problems. The existing data is sometime inadequate for real-life problem solving since human calculation on preferences is unclear and unpredictable with the exact numeric score [4] and [5]. So, it needs new a model to perform measurement. This research uses fuzzy logic model in the decision making of structured choice. Fuzzy logic helps measure the concept of uncertainty related to subjective human. Fuzzy AHP is used to calculate the value of the criteria and Fuzzy TOPSIS is used to decide the ranking of selected alternatives.

II. BASIC THEORY

A. Business Process Management

Business Process Management is method and technique used to support business process in terms of modeling, controlling, and analyzing process that involve process subject, organization, application, document and other information input [6]. Business process management aims to get a good and efficient business process for the organization.

B. Risk Management

One of the main focuses of IT governance is risk management, it is very important and interesting topic for many organizations as it covers the organization's success in reaching its early stated goals and eliminating possible failures [7]. So, risk management has an important role in the overall management system [8].

C. Maturity Index

Maturity index is an index of maturity level in COBIT. Maturity model for management and control over IT process is based on organizational evaluation method, so it can be judged from the level of maturity that does not exist (0) to be optimized (5). [9]

Control Objectives for Information and related technology (COBIT) is created and distributed by Information System Audit and Control Association (ICASA) [10] COBIT is a standard in the framework domain consists of a set of IT processes that present controllable and structured activities [11]. COBIT framework provides domain process models that are commonly discovered in IT Activities, such as: Plan and Organize (PO), Acquire and Implement (AI), Deliver and Support (DS) and Monitor and Evaluate (ME).

IT governance focus areas on Risk Management has supporting processes as follows:

TABLE I. IT TABLE PROCESS SUPPORTS IT GOVERNANCE BASED ON COBIT

(Source: [11])

Governance Focus Area	Supporting processes	
	Primary	Secondary
Risk Management	PO4, PO6, PO9, The DS2, DS4, DS5, DS11 DS12, ME2 ME3 ME4,,	PO1, PO2, PO3, PO7 PO8,, AI1, AI2, PO10, AI4, AI7, DS3, DS7, DS9, DS10, ME1

D. Fuzzy Analitical Hierarchy Process (FAHP)

Fuzzy Analitical Hierarchy Process (FAHP) Method is proposed for the first time by Chang and this is a development of AHP method created by Saaty which FAHP is a method consists of AHP matrixes represented or filled by fuzzy number [12][14].

FAHP uses fuzzy ratio called by Triangular Fuzzy Number (TFN) and used in the calculation process. Triangular Fuzzy Number consists of three function criteria scores, namely the lowest score (l), the middle score (m), and the highest score (u).

The step in performing FAHP is as follows [4]:

1. Arranging the problems in the form of hierarchy

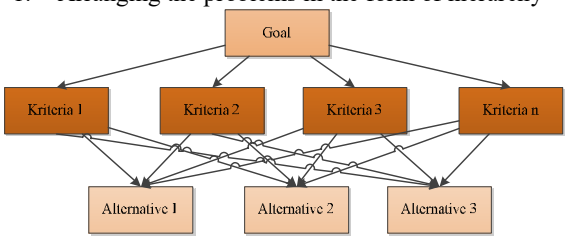

Fig. 1. Problem Hierarchy Structure

2. Establishing the weight of each predefined criteria using fuzzy triangle (TFN) score that indicates the comparing of importance among the criteria.

TABLE II. VARIABLE LINGUISTIC SCORE WITH TRIANGULAR FUZZY NUMBER [13]

Variable Linguistic	Value TF	Value Invers TF
Equal Importance (EI)	1 1 1	1 1 1
Moderate Importance (MI)	1 3 5	1/5 1/3 1
Strong Importance (SI)	3 5 7	1/7 1/5 1/3
Very Strong Importance (VSI)	5 7 9	1/9 1/7 1/5
Extreme Importance (EI)	8 9 10	1/10 1/9 1/8

Triangular Fuzzy Figure in table 1 is denoted by M = {l, m, u}, which M is a matrix of fuzzy number consists of l (lowest score), m (medium/nearest score) and u (biggest score).

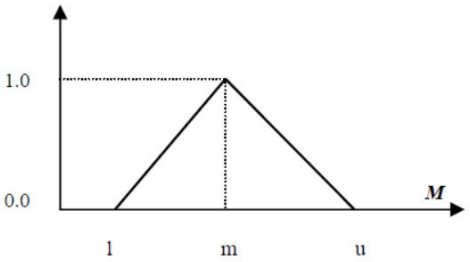

Fig. 2. Triangular Fuzzy Number (TFN)

If X={x1,x2,x3,..xn} indicates a set of objects, and Y={y1,y2,y3,…yn} indicates stipulated goals. If there are number of analyzed m criteria, then it is obtained that M yi1, M yi2, M yi.3 ... M yi.mi = 1,2, ...,n, which Myi j (j = 1, 2, ..., n) triangular fuzzy number.

3. Determine fuzzy synthesis score with the criteria of I using the formula of 1.

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{i=1}^{n} \sum_{j-1}^{m} M_{gi}^{j} \right]^{-1}$$

Formula 1

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, it is calculated using formula 2.

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right)$$

Formula 2

To obtain $\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$, it is conducted sum of fuzzy score using formula 3.

$$\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{n} l_j, \sum_{j=1}^{n} m_j, \sum_{j=1}^{n} u_j \right)$$

Formula 3

Next, count the inverse score of matriks in formula 3 using formula 4.

$$\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{j=1}^{n} l_j}, \frac{1}{\sum_{j=1}^{n} m_j}, \frac{1}{\sum_{j=1}^{n} u_j} \right)$$

Formula 4

4. Calculate level of possibility, which A1 = (l1, m1, u1) and A2 = (l2, m2, u2) is two of TFN, so level of possibility of A2 = (l2, m2, u2) ≥ (l1, m1, u1) it is from the formulation of formula (5) and (6).

$$V = A_2 \geq A_1 = hgt\,(A_2 \cap A_1) = \mu_{M2}$$

Formula 5

$$= \begin{cases} 0 & , if \quad m_2 \geq m_1 \\ 1 & , if \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & , otherwise \end{cases}$$

Formula 6

5. Compare level of possibility between fuzzy A1 number = (i=1, 2,…k) with the formula 7.

$$\begin{aligned} &P(A \geq A_1, A_2, \ldots A_k) \\ &= P[(A \geq A_1)] \text{ and } (A \geq A_2) \text{ and } \ldots \text{ and } (A \geq A_k)] \\ &= {}_{min}\, P(A \geq A_1),\ i = 1,2,\ldots,k \end{aligned}$$

Formula 7

With the estimation of d (Ni) = minP (Si ≥ Sj) for j = 1,2, ... j; j ≠ i. so we obtain value of weight vector on the formula (8).

$$W' = (d'(N_1), d'(N_2), \ldots, d'(N_n))^T$$

Formula 8

After the formula (8) is normalized, the obtained normal weight vector can be calculated using formula (9).

$$W = (d(N_1), d(N_2), \ldots, d(N_n))^T$$

Formula 9

Which found W is not a Fuzzy score.

E. Fuzzy TOPSIS

After the criteria calculated using Fuzzy AHP, then it conducted an alternative ranking using TOPSIS method that has been using fuzzy numbers. Fuzzy TOPSIS uses fuzzy triangle number as in illustration 3 to describe the score for each of selected alternative.

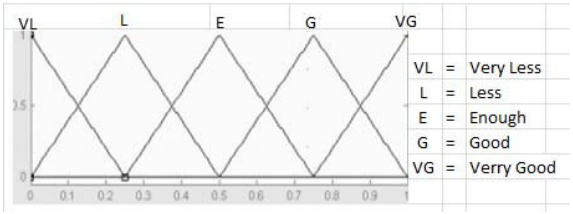

Fig. 3. Fuzzy Number for Alternative Assessment

After each specified alternative is assigned a value, we can calculate the total integral weight for each alternative using the formula (10).

$$x = I(F) = ½\,(ac+b+(1-a)a)$$

Formula 10

With h α is a level of optimism by the grade between 0 and 1. After obtaining the total integral weight for each criterion, it is subsequently normalized by the formula (11).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Formula 11

Followed by performing calculation to obtain a normalized weight matrix through formula (12).

$$v_{ij} = W_{ij} * r_{ij}$$

Formula 12

Continued by calculate the score of positive ideal solution and negative ideal solution using formula (13).

$$A^+ = \{v_1^+, v_2^+, ..., v_n^+\}$$
$$A^- = \{v_1^-, v_2^-, ..., v_n^-\}$$

Formula 13

Range between alternatives with positive ideal solution is calculated using the formula (14).

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}$$

Formula 14

Meanwhile, the alternative range to the ideal solution is calculated by the formula (15).

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

Formula 15

By compare the range with the positive and negative ideal solution, then it is calculated the preference for each alternative by the formula (16).

$$CC_i = \frac{D_i^-}{D_i^- + D_i^+}$$

Formula 16

The calculated value of formula (16) is the final score used to decide the alternative based on the largest value of CC_i.

Combination between the two Fuzzy methods (Fuzzy AHP and Fuzzy Topsis) at this paper, illustrates how fuzzy AHP and Fuzzy Topsis can be integrated to allow a more consistent evaluation and prioritize the smallest weight of the criteria to be improved (with fuzzy AHP) and to determine the ranking of the alternatives that have been selected (with fuzzy topsis).

III. RESEARCH METHODOLOGY

The designed research model is shown in Figure 4.

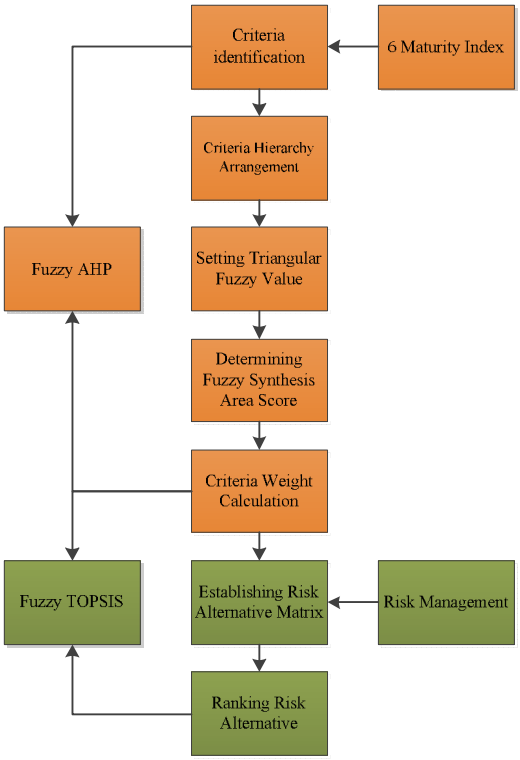

Fig. 4. Research Methode

First, this study was to decide the criteria. The used criteria were taken from 6 COBIT maturity indexes, 0 Non-Existent, 1 Initial/Ad Hoc, 2 Repeatable but Intuitive, 3 Defined, 4 Managed and Measurable 5 Optimized. After obtaining the criteria, the calculation was conducted using FAHP started by making pairwise comparison matrixes from the maturity index to measure the fuzzy synthetic score so we obtain the weight of each criteria.

The calculated weight using FAHP was used to rank the risk management search by using Fuzzy TOPSIS. Risk management in this study included: Hardware (Damaged or Missing), Database Server (vital asset because it was used as a whole sensitive data storage from simple to complex data), SI Application (The main system used by companies to enter data and producing report), Infrastructure, Network and Employees (employees as a whole were trained in the use of Application and security awareness of application usage, data theft, etc.) determined by checking business process using YAWL.

IV. RESULT

The first step is to know the criteria by considering the index value of maturity index in 6 attributes of COBIT maturity includes: 0 Non-Existent, 1 Initial / Ad Hoc, 2 Repeatable but Intuitive, 3 Defined, 4 Managed and Measurable 5 Optimized.

For each used criterion used, the weight of M is given to represent the ratio among the criteria to each other. The ratio between all criteria or attributes is set to get the matrix as in Table 2.

TABLE III. COMPARISON MATRIX OF PAIR FUZZY SCORE OF COBIT MATURITY INDEX.

Criteria	Non-existent			Initial/Ad hoc			table but Ins			Defined			and Me			Optimised		
Non-existent	1	1	1	1	3	5	3	5	7	1	3	5	1	1	1	1	1	1
Initial/Ad hoc	1/5	1/3	1	1	1	1	1/5	1.3	1	3	5	7	3	5	7	3	5	7
Repeatable but Instuitive	1/7	1/5	1/3	1	3	5	1	1	1	1	3	5	1	3	5	3	5	7
Defined	1/5	1/3	1	1/7	1/5	1.3	1/5	1.3	1	1	1	1	1	3	5	1/5	1/3	1
Managed and Measurable	1	1	1	1/7	1/5	1.3	1/5	1.3	1	1/5	1/3	1	1	1	1	1	1	1
Optimised	1	1	1	1/7	1/5	1.3	1/7	1/5	1/3	1	3	5	1	1	1	1	1	1

Next, it is calculated the weight of fuzzy Synthetic extents (Si) using the formula (1), and the result is seen in table 4.

TABLE IV. SYNTHETIC EXTENTS SCORE

Criteria	L	M	U
Non-existent	8.0000	14.0000	20.0000
Initial/Ad hoc	10.4000	16.6667	24.0000
Repeatable but Instuitive	7.1429	15.2000	23.3333
Defined	2.7429	5.2000	9.3333
Managed and Measurable	3.5429	3.8667	5.3333
Optimised	4.2857	6.4000	8.6667
Number of Columns	36.1143	61.3333	90.6667

Then, it is used the formula (3) to calculate the weight of each criteria level. The generated matrix calculation score from table 4 are calculated by the formula (8) as in table 5. (W ').

TABLE V. WEIGHT VECTOR SCORE

Criteria	on-existen	itial/Ad h	ble but In	Defined	and Me	Optimised
Non-existent	1	1.0816	1.0363	0.5426	0.2646	0.5505
Initial/Ad hoc	0.9099	1	0.9569	0.4346	0.1364	0.4280
Repeatable but Instuitive	0.8824	1.0549	1	0.5242	0.2716	0.5291
Defined	1.6690	1.9181	1.7970	1	0.8438	1.1029
Managed and Measurable	2.2911	2.5882	2.3929	1.5763	1	1.2588
Optimised	1.8375	2.1092	1.9655	1.1105	0.6291	1

Then, it is conducted normalization for each criterion, so there is a vector score shown in Table 5.

TABLE VI. WEIGHT NORMALIZATION

Criteria	on-existen	itial/Ad h	ble but In	Defined	and Me	Optimised
W'	0.8824	1	0.9569	0.4346	0.1364	0.4280
W	0.2299	0.2605	0.2493	0.1132	0.0355	0.1115

The weight of vector score generated from the calculation using Fuzzy AHP method is used to calculate the alternative ranking value taken from each risk using TOPSIS method. The identification of used alternatives in this study refers to some of the identified risks SOP using YAWL application, such as: Hardware (Damaged or Missing), Database Server (vital asset because it is used as a sensitive data storage from simple data to complex), Information System Application, Infrastructure, Network and Employees (employees as a whole are trained in application use and security awareness of application use, data theft, etc.)

Each risk criteria are assigned using a fuzzy triangle (TFN), as in Table 7.

TABLE VII. ALTERNATIVE VALUE NORMALIZATION

Criteria	Non-existent			Initial/Ad hoc			peatable but Instuiti			Defined			naged and Measura			Optimised		
Infrastructure	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.75	1	1
Network	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.75	1	1	0.75	1	1	0.75	1	1
Q-Pro Application	0	0.25	0.5	0.5	0.75	1	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.75	1	1
Hardware	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	0.5	0.75	1
Database Server	0	0.25	0.5	0.5	0.75	1	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	0.5	0.75	1
Employee	0	0.25	0.5	0.25	0.5	0.75	0.25	0.5	0.75	0	0.25	0.5	0	0.25	0.5	0.25	0.5	0.75

Thereafter, the score obtained from Table 7 are calculated using the formula 10 to obtain the integral total value and the obtained X matrix as shown in Table 8.

TABLE VIII. INTEGRAL SCORE TABLE

Criteria	Non-existent	Initial/Ad hoc	peatable but Instuiti	Defined	naged and Measura	Optimised
Infrastructure	0.4375	0.4375	0.4375	0.75	0.75	0.96875
Network	0.4375	0.75	0.75	0.96875	0.96875	0.96875
Q-Pro Application	0.125	0.75	0.4375	0.75	0.75	0.96875
Hardware	0.4375	0.4375	0.4375	0.4375	0.4375	0.75
Database Server	0.125	0.75	0.4375	0.4375	0.4375	0.75
Employee	0.125	0.4375	0.4375	0.125	0.125	0.4375

Normal v weight matrix is calculated using formula (11) and (12) in table 8, so that the result of matrix V can be seen in Table 9 below:

TABLE IX. NORMALIZATION WEIGHT MATRIX

Criteria	Non-existent	itial/Ad ho	atable but Instu	Defined	ged and Measu	Optimised
Infrastructure	0.1276	0.0758	0.0885	0.0541	0.0170	0.0531
Network	0.1276	0.1299	0.1517	0.0699	0.0219	0.0531
Q-Pro Application	0.0365	0.1299	0.0885	0.0541	0.0170	0.0531
Hardware	0.1276	0.0758	0.0885	0.0316	0.0099	0.0411
Database Server	0.0365	0.1299	0.0885	0.0316	0.0099	0.0411
Employee	0.0365	0.0758	0.0885	0.0090	0.0028	0.0240

Then, it is calculated the value of ideal positive solution score and ideal negative score in the normalized weight matrix in table 8 using the formula (13), the distance between the positive ideal solution alternative (Di^{+}) is calculated using the formula (14), while the range alternative of negative ideal solution (Di^{-}) is calculated by using the formula (15).

By comparing the range between a positive ideal solution and a negative ideal solution, a preference score for each of alternatives determined in Table 10 is calculated using formula (16).

TABLE X. RISK ALTERNATIVE RANKING

Criteria	Cci	Rank
Infrastruktur	1.0848	4
Jaringan	1.0000	5
Aplikasi SI	1.1122	2
Hardware	1.0932	3
Database Server	1.1186	1
Karyawan	0.1420	6

V. CONCLUSION

This research is to determine and evaluate maturity index and risk management in the implementation of IT governance using Fuzzy AHP and Fuzzy TOPSIS at PT. X. The results indicate that Managed and Measurable maturity index has the smallest weight of 0.0355 compared to other criterian (That means companies do not reach maturity levels to understand risks in "managed and measure: Management monitors and measures compliance to procedures and takes action if the process cannot be done effectively") and Database Server obtains very serious attention because the score is very high compared to another alternative with 1.1186. Then, it is necessary to take strategic steps from the company to prevent or improve the risk that may occur.

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