Model for Measuring benefit of Government IT Investment using Fuzzy AHP

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***Abstract*—Information Technology (IT) has become a mandatory for every organization including government. Investment on IT can help government to deliver services to the citizen. Every IT investment should give the maximum result. Measurement for the benefit of IT investment is needed to make sure that it has deliver the missions and goals. There are plenty models for measuring the feasibility of an IT investment before the implementation. But there are still few models to measure the IT investment after implementation. This paper proposes a model to measure the benefit of an IT investment after implementation, especially in government organizations. The model uses generic IS/IT business value category which consists of 13 categories and 73 sub-categories. Each category will be weighted according to organization preference using Fuzzy Analitic Hierarchy Process (FAHP). This model is applied to measure IT investments in the Ministry of Finance of the Republic of Indonesia, named SPAN and SAKTI applications. The weighted benefit score of SPAN is 76.39%, while the original score is 75.89%. The weighted benefit score of SAKTI is 68.08%, while the original score is 67.33%. The differences between the original score and weighted score indicate that the model accommodates the organization's preference in the evaluation.**

Keywords—IT investment; government investment; ex-post evaluation; benefit creation; fuzzy AHP; analytic hierarchy process

I. Introduction

The use of Information Technology (IT) will increase the atmosphere of openness and transparency [1]. Thus, IT can be used by the Government to deliver transparent and accountable services. Investment in IT by Government is needed to support the organization. The IT investment that has been implemented by the government needs to be evaluated as an embodiment of accountable governance. According to the IT governance framework, The Control Objectives for Information and Related Technology (COBIT) version 5, in the EDM02 process -Ensure Benefits Delivery, organizations must be able to ensure that IT benefits have actually been achieved and are received by all stakeholders.

After an investment being implemented, there is a need to measure that the benefit of investment has been delivered to the stakeholder. The measurement problem is a significant factor that becomes an obstacle in evaluation [2][3]. It is difficult to identify the benefits in ex-post evaluations [4]. That is because of the different systems used by various business areas so that the benefits of each business area can be varied. The evaluation is complicated because the definition of success is unclear and varies from one organization to another [5]. The unclear definition of benefit/value makes an imbalance between theory and practice [6].

Ex-post evaluation models for government IT investments are still very limited in number. Some ex-post IT investment evaluation models used by governments in the world like Social Return on Investment (SROI), Balanced E-Government Index (BEGIX), Public Sector Value Model (PSV), Performance Reference Model (PRM), Interchange of Data between Administration Value of Investment (IDA VOI), Method of Analysis and Value Enhancement (MAREVA), E-Gov Economics Projects (eGEP) [7][8]. Some of the above models (SROI, BEGIX, IDA VOI, MAREVA) use financial-based to measure the benefit/value creation. While for government institutions, it is not always about financial benefit. A literature review on Information and Communication Technologies (ICT) project evaluation by AL-Ghamdi et al [9] found that the post implementation evaluation approach of the ICT project in common practice are assessing non-financial ICT business values. The PRM model focuses more on organizational performance in general and not on the impact of IT investment results. Although the PSV model does not measure the value of money, it does not show the specific value obtained from the IT investment. While the eGEP model is very broad in scope, its measurement is not suitable for measuring a single IT investment by the government. Setiawan et al [10] proposed a hybrid method for evaluating the performance of ICT projects. Although the methods can be used to evaluate the performance of ICT projects, it cannot determine what benefits are created from the ICT projects being evaluated.

Therefore, there is a need to develop a new ex-post evaluation method that can show the benefit/value of an IT investment, especially in government organizations. It should overcome the problem of benefit differences in various organizations. Also, the method should accommodate the organization's preference in the evaluation. This study proposed a model for identifying benefit creation of an IT investment in government organizations. The benefit created will be scored and weighted according to decision makers in the organization.

This paper is divided into six sections: the first section is the introduction, the second and third sections are the literature review, the fourth section is the research methodology, the fifth sections present the result and discussion, and the last section present the conclusions generated from this research.

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II. Generic IS/IT Business Value Template

The generic IS/IT Business value template was proposed by Ranti [11]. The IS/IT business value template consists of 13 benefit categories and 73 benefit sub-categories, they are:

1) Reducing Cost of (traveling cost, staff/operator/ employee cost, meeting cost, service failure cost, application development cost, delivery cost, training cost per employee, returning cost for incorrect delivery, cost of money, office supplies and printing cost, subscription cost of certain reading materials or subscription cost per employee, space rental cost, device rental cost, inventory cost, research failure cost).

2) Increasing Productivity caused by (restructuring job function, accelerating mastering product knowledge, ease of analysis, increasing employee satisfaction).

3) Accelerating Process of (production process, stock procurement process, report making process, data preparation process, order checking process, debt payment process, transaction process, decision-making process).

4) Reducing Risk of (price miscalculation, unrecoverable claim, inventory lost, rejected goods, data lost, incorrect data, penalty, losing potential employee, forgery, administration fraud, incorrect payment, asset mismanagement).

5) Increasing Revenue caused by (increasing business capacity, increasing report quality, increasing customer trust, widening market segment, increasing other incomes).

6) Increasing Accuracy of (billing, analysis, data, planning, decision).

7) Accelerating Cash-in caused by (accelerating billing dispatching).

8) Increasing External Services of (reducing order cancellation, knowing customer's problems, adding a point of services, personalized services, customer satisfaction).

9) Increasing Image caused by (increasing service quality, offering substantial discounts, complying with regulations, using branded systems).

10) Increasing Quality of (better supplier/vendor management, work result, services, products).

11) Increasing Internal Services of (shared services, matching employee's right and responsibility, employee services, proper schedule, and training material).

12) Increasing Competitive Advantage caused by (forming business alliances, accelerating the execution of new business opportunities, increasing switching costs).

13) Avoiding Cost of (reserved fund, maintenance cost, lost and delay cost).

This template could be used to overcome the problem of benefit differences in various organizations. The generic IS/IT Business value template will be used as a base for measurement.

III. Fuzzy AHP

Analytic Hierarchy Process (AHP) is a method proposed by Saaty [12][16] for selecting alternatives using distinct criteria. The AHP method breaks a complex and unstructured problem into several components in a hierarchical arrangement. The decision-maker makes a pairwise comparison between criteria. This method can be used for weighting the criteria for decision making. AHP deals with a crisp number to represents the judgment by the decision-maker. The intensity scale of importance converted into a number for computation.

Fuzzy AHP (FAHP) method proposed by Laarhoven and Pedrycz [13] is an extension of AHP using fuzzy concept. The scale of importance is represented in fuzzy using Triangular Fuzzy Number (TFN) (Table I). FAHP could deal with subjective judgment in making priorities. Sehra et al. demonstrated the different results of software quality model selection using AHP and FAHP [14].

Using Extend Analysis by Chang [15], Fuzzy AHP technique is divided into several steps:

1) Creating a pairwise comparison matrix between categories in the TFN scale.

2) Calculating the fuzzy synthetic extents ($\tilde{S}_x$) of the above matrix on category *x* with the equation:

$$(\tilde{S}_x = \sum_{y=1}^{n} \tilde{C}_{xy} \otimes \left[\sum_{k=1}^{n}\sum_{y=1}^{n} \tilde{C}_{ky}\right]^{-1}; \text{x=1, 2, ..., n} \quad (1)$$

Where $\otimes$ denotes the extended multiplication of two fuzzy numbers, n is the size of the pairwise comparison matrix between categories, and k is a combination of criteria from line i where i = 1 to n.

$$\sum_{y=1}^{n} \tilde{C}_{xy} = \left(\sum_{y=1}^{n} l_{xy}, \sum_{y=1}^{n} m_{xy}, \sum_{y=1}^{n} u_{xy}\right); \text{x=1, 2, ..., n} \quad (2)$$

where l is the lower bound, m is the middle bound, u is the upper bound.

$$\left[\sum_{k=1}^{n}\sum_{y=1}^{n} \tilde{C}_{ky}\right]^{-1} = \left[\frac{1}{\sum_{k=1}^{n}\sum_{y=1}^{n} u_{ky}}, \frac{1}{\sum_{k=1}^{n}\sum_{y=1}^{n} m_{ky}}, \frac{1}{\sum_{k=1}^{n}\sum_{y=1}^{n} l_{ky}}\right] \quad (3)$$

$$\sum_{k=1}^{n}\sum_{y=1}^{n} \tilde{C}_{ky} = \left(\sum_{k=1}^{n}\sum_{y=1}^{n} l_{ky}, \sum_{k=1}^{n}\sum_{y=1}^{n} m_{ky}, \sum_{k=1}^{n}\sum_{y=1}^{n} u_{ky}\right) = \left[\left(\sum_{y=1}^{n} l_{1y}, \sum_{y=1}^{n} m_{1y}, \sum_{y=1}^{n} u_{1y}\right) + \cdots + \left(\sum_{y=1}^{n} l_{ny}, \sum_{y=1}^{n} m_{ny}, \sum_{y=1}^{n} u_{ny}\right)\right] \quad (4)$$

3) Comparing the fuzzy synthetic extents ($\tilde{S}_x$) of one category with another fuzzy synthetic extents category ($\tilde{S}_y$), which is called as degree of possibility with equation:

$$V(\tilde{S}_x \geq \tilde{S}_y) \begin{cases} 0, \text{if } m_x \geq m_y \\ 1, \text{if } l_y \geq u_x \\ \frac{l_y - u_x}{(m_x - u_x) - (m_y - l_y)}, \text{otherwise} \end{cases} \quad (5)$$

Where $V(\tilde{S}_x \geq \tilde{S}_y \mid \text{y} = 1, \ldots, \text{n}); \text{y} \neq \text{x}$

4) Determining the minimum degree of possibility of $V(\tilde{S}_x \geq \tilde{S}_y)$

$$d'(A_x) = \min V(\tilde{S}_x \geq \tilde{S}_y) \quad (6)$$

Then the weight vector (W') is given by

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T \quad (7)$$

Where $A_1 (i = 1,2, \ldots, n)$ are n elements.

TABLE. I. TRIANGULAR FUZZY NUMBER

Linguistic Variable	Positive TFN	Positive Reciprocal TFN
Extremely Strong (ES)	(9,9,9)	(1/9,1/9,1/9)
Intermediate value	(6,8,9)	(1/9,1/8,1/6)
Very Strong (VS)	(5,7,9)	(1/9,1/7,1/5)
Intermediate value	(4,6,8)	(1/8,1/6,1/4)
Strong (S)	(3,5,7)	(1/7,1/5,1/3)
Intermediate value	(2,4,6)	(1/6,1/4,1/2)
Moderately Strong (MS)	(1,3,5)	(1/5,1/3,1)
Intermediate value	(1,2,4)	(1/4,1/2,1)
Equally Strong (EqS)	(1,1,1)	(1,1,1)

5) Then the normalized importance weight vector W of the *pairwise comparison* are:

$$W = \left(d(A_1), d(A_2), \dots, d(A_n)\right)^T \quad (8)$$

where W is a nonfuzzy number that represents the priority weights of an attribute or an alternative over another.

IV. RESEARCH METHODOLOGY

The proposed model is for measuring the benefit generated by an IT investment in government organizations. To identify the benefit, this model is using the Generic IS/IT Business Value Template. The use of the template is intended to overcome the problem of benefit differences in various organizations. Secondly, this model will use Fuzzy AHP to weighting the benefit category. The weighting process is needed to accommodate the organization's preference.

The first step of the proposed model is to determine the categories and subcategories of business benefits that are created with IT investment. This step will be carried out by distributing questionnaires to stakeholders involved in implementing IT investments. With this questionnaire method, we will get benefit categories and subcategories that have contributed to the creation of benefit with IT investment. In the survey respondents are choosing the benefit creation from each benefit sub-category based on their experiences. Respondents fill based on personal experience in the field by following intuition, experience, data, information and critical level possessed by the assessor [17]. Filling in the benefit creation by using a scale in lingual form with the following percentage ranges:

a) Very high benefits ((80-100%])

b) High benefits ((60-80%])

c) Medium benefits ((40-60%])

d) Low benefits ((20-40%])

e) Very low benefits ((0-20%])

f) No benefits created (0%)

The results of the questionnaire then processed to obtain the benefit score. The score of benefit categories is the average score of the benefit sub-categories from particular categories. The score of each benefit categories then multiplied by the weight of the categories. The weight of each benefit categories is made by decision-maker using pairwise comparison between the categories. The result of comparison is then processed by the Fuzzy AHP method to get the importance weight of each benefit category. The final score of benefit creation is the sum of the weighted values of each benefit category.

To validate the proposed model, the model has been used to evaluating two IT investment in the Ministry of Finance of the Republic of Indonesia (MoF), i.e.

1) Sistem Perbendaharaan dan Anggaran Negara (SPAN) (State Treasury and Budget Application System).

2) Sistem Aplikasi Keuangan Tingkat Instansi (SAKTI) (Institution-level Financial Application System).

SPAN is an IT investment made by MoF to integrate and centralize the financial management information system in Indonesia. It replaced the old system which was distributed across the country. SAKTI is also an IT investment made by MoF to integrate many financial application in the operating ministries. SPAN and SAKTI application now support the new financial system for the Government of the Republic of Indonesia.

V. RESULT AND DISCUSSION

To collect the opinion from the stakeholder, questionnaire has been given to the user to measure the benefit creation based on their experience. The questionnaire is based on the Generic IS/IT Business value template. For weighting the category, the decision-maker in the organization makes a pairwise comparison between the benefit categories. There are 13 benefit categories, i.e reducing cost (C1), increasing productivity (C2), accelerating process (C3), reducing risk (C4), increasing revenue (C5), increasing accuracy (C6), accelerating cash-in (C7), increasing external services (C8), increasing image (C9), increasing quality (C10), increasing internal services (C11), increasing competitive advantage (C12), and avoiding cost (C13). The result of the pairwise comparison in the TFN scale is presented in Table II.

Using extent analysis by Chang (equation 1 to 8), the result of importance weight vectors after normalization is presented in Table III. The weight value of the benefit category summarized and presented in Table IV. The weight of the benefit category then used for calculating the total benefit created from the IT investment.

The questionnaire was given to the SPAN and SAKTI applications users. There are 30 respondents for each application. The score of each benefit category is obtained from the average score of sub-categories benefit in the same category. The benefit score then multiplied by the weight of the benefit category. The final benefit score is the sum of the weighted score of all benefit categories. The result is shown in Table V and Table VI.

The result of SPAN investment, the total weighted benefit score (76.39%) is higher than the original score (75.89%). This indicates that some benefit categories with high priority has a higher score among others. On the other hand, the top priority benefit category (reducing risk) has a score of 78.11% that categorized as a high benefit. And the least score of benefit category belongs to benefit "increasing competitive advantage" which is the 7th priority out of 13.

TABLE. II. PAIRWISE COMPARISON IN TFN

	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			C11			C12			C13		
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u
C1	1	1	1	1	3	5	1	3	5	1	3	5	1	1	1	1	1	1	1	3	5	1	1	1	1	3	5	1	1	1	1	3	5	1	1	1	1	1	1
C2	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5	1	1	1	1	1	1	1	1	1	1	3	5	1	1	1
C3	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
C4	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
C5	1	1	1	1	1	1	1	1	1	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5	1	1	1	1	3	5
C6	1	1	1	1	1	1	1	1	1	0,2	0,33	1	1	1	1	1	1	1	1	3	5	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5	1	3	5
C7	0,2	0,33	1	1	1	1	0,2	0,33	1	0,2	0,33	1	1	1	1	0,2	0,33	1	1	1	1	1	1	1	1	3	5	1	1	1	1	1	1	5	7	9	1	1	1
C8	1	1	1	0,2	0,33	1	0,2	0,33	1	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C9	0,2	0,33	1	1	1	1	0,2	0,33	1	0,2	0,33	1	1	1	1	1	1	1	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C10	1	1	1	1	1	1	0,2	0,33	1	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C11	0,2	0,33	1	1	1	1	0,2	0,33	1	0,2	0,33	1	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C12	1	1	1	0,2	0,33	1	0,2	0,33	1	0,2	0,33	1	1	1	1	0,2	0,33	1	0,11	0,14	0,2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5
C13	1	1	1	1	1	1	0,2	0,33	1	0,2	0,33	1	0,2	0,33	1	0,2	0,33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,2	0,33	1	1	1	1

TABLE. III. NORMALIZED IMPORTANCE WEIGHT

	d(A1)	d(A2)	d(A3)	d(A4)	d(A5)	d(A6)	d(A7)	d(A8)	d(A9)	d(A10)	d(A11)	d(A12)	d(A13)
W	0,1234	0,0842	0,1279	0,1379	0,0478	0,0948	0,0870	0,0478	0,0468	0,0489	0,0468	0,0610	0,0457

TABLE. IV. WEIGHT OF BENEFIT CATEGORY

	Benefit Category	**Weight**
C1	Reducing Cost	0,1234
C2	Increasing Productivity	0,0842
C3	Accelerating Process	0,1279
C4	Reducing Risk	0,1379
C5	Increasing Revenue	0,0478
C6	Increasing Accuracy	0,0948
C7	Accelerating Cash-in	0,0870
C8	Increasing External Services	0,0478
C9	Increasing Image	0,0468
C10	Increasing Quality	0,0489
C11	Increasing Internal Services	0,0468
C12	Increasing Competitive Advantage	0,0610
C13	Avoiding Cost	0,0457

TABLE. V. SPAN BENEFIT SCORE

	Benefit Category	**Score**	**Weight**	**Weighted Score**
1	Reducing Cost	72,28	0,1234	8,9192
2	Increasing Productivity	77,00	0,0842	6,4848
3	Accelerating Process	78,67	0,1279	10,0629
4	Reducing Risk	78,11	0,1379	10,7722
5	Increasing Revenue	71,48	0,0478	3,4175
6	Increasing Accuracy	80,90	0,0948	7,6684
7	Accelerating Cash-in	79,83	0,0870	6,9468
8	Increasing External Services	75,16	0,0478	3,5933
9	Increasing Image	76,32	0,0468	3,5682
10	Increasing Quality	79,00	0,0489	3,8639
11	Increasing Internal Services	76,00	0,0468	3,5534
12	Increasing Competitive Advantage	68,92	0,0610	4,2016
13	Avoiding Cost	72,94	0,0457	3,3370
	Total	**75,89**[a]		**76,39**

[a]average

TABLE. VI. SAKTI BENEFIT SCORE

	Benefit Category	Score	Weight	Weighted Score
1	Reducing Cost	63,43	0,1234	7,8275
2	Increasing Productivity	68,98	0,0842	5,8097
3	Accelerating Process	71,64	0,1279	9,1643
4	Reducing Risk	71,03	0,1379	9,7958
5	Increasing Revenue	57,75	0,0478	2,7611
6	Increasing Accuracy	75,55	0,0948	7,1610
7	Accelerating Cash-in	66,43	0,0870	5,7807
8	Increasing External Services	62,91	0,0478	3,0077
9	Increasing Image	64,36	0,0468	3,0093
10	Increasing Quality	70,05	0,0489	3,4260
11	Increasing Internal Services	70,98	0,0468	3,3185
12	Increasing Competitive Advantage	64,00	0,0610	3,9015
13	Avoiding Cost	68,13	0,0457	3,1167
	Total	**67,33**[b]		**68,08**

[b]average

The similar results gained for SAKTI investment. The total weighted benefit score (68.08%) is higher than the original score (67.33%). It also indicates that some benefit categories with high priority has a higher score among others. The top priority benefit category (reducing risk) got score 71.03% that categorized as high benefit. While the least score of benefit category belongs to benefit "increasing revenue" with score of 57.75% that categorized as a medium benefit.

From those two IT investments, the final score of the benefit creation is categorized as "high benefits". This category still can be improved to become a "very high benefits" category. The leader of the organization could use the results of these measurements as a base for evaluation to improve the achievement of IT investment benefits.

VI. CONCLUSION AND FUTURE WORK

Based on the result and discussion, the proposed model could fulfill the research objectives. First, the model can overcome the problem of differences in the benefits criteria between organizations and can measure the benefits created from an IT investment in government organizations. Second, the differences between the score using FAHP weighting and the original score indicates that the model accommodates the organization's preference in the evaluation. Third, the proposed model can be a supporting tool to meet the requirements of COBIT 5 framework, especially in the EDM02 process - Ensure Benefits Delivery.

For future work, researchers can develop new business value templates that are better suited to the nature of government organizations. In addition, researchers can also try other weighting methods and compare the results with the results of the Fuzzy AHP method.

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