A Fuzzy Analytic Hierarchy Process Approach for Determining the Criteria Success Factors of MRT Parts' e-Procurement: the Case of Jakarta MRT Project

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A Fuzzy Analytic Hierarchy Process Approach for Determining the Criteria Success Factors of MRT Parts' e-Procurement: the Case of Jakarta MRT Project

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Abstract. The Mass Rapid Transit (MRT) project is conducted by the central government in cooperation with the provincial government of DKI Jakarta and supported by the Japanese government through Japan International Cooperation Agency (JICA). The government goal is to create good e-Governance for the MRT project, and together initiate the use of e-Supply Chain Management (e-SCM), especially the e-Procurement, for the entire project. Technological innovation which is collaborated within the e-SCM becomes a very important aspect to support the e-Governance. This paper aims to determine the criteria and sub-criteria of success of the implementation of MRT parts' e-Procurement, and to determine the priorities of the MRT parts' e-Procurement process for the provincial government of DKI Jakarta. Fuzzy Analytic Hierarchy Process was employed to explore and simulate the level of importance of criteria and sub-criteria, in relations with the successful implementation of e-Procurement in MRT project. Top management commitment was found to be the most influential criteria by 0.334, followed by government policy and regulation (0.305), technology infrastructure (0.176), value acquisition (0.103), and suppliers' relations (0.082).
Keywords: MRT, e-SCM, e-Procurement, Fuzzy AHP, Criteria Success Factors.

1. Introduction

The Mass Rapid Transit (MRT) project development process requires several related agencies to fulfil the need for components. One important component is the drilling machine known as the Tunnel Boring Machine (TBM) which consists of the drill component (cutter head), body block, and motor house. TBM is produced by JTSC (Japan Tunnel Systems Corporation). In addition, required related components include mechanical and electrical, and infrastructure systems (e.g. accommodation facilities such as escalators for underground access, gate systems, railway tracks, carriages along with moving trains, human resources as control aspects, and maintenance-related spare parts).

The MRT project is conducted by the central government in a cooperation with the provincial government of DKI Jakarta and supported by the Japanese government through Japan International Cooperation Agency (JICA). The government goal is to create good e-Governance for the MRT project, and together initiate the use of e-Procurement for the entire project. Based on previous experience in other countries, Government to Business (G2B) collaboration sometimes generate challenges on how to relate and integrate each process during the projects [1]. E-Procurement is important because it is proven to improve transparency, efficiency, effectiveness, accountability, fairness, interoperability, and data security assurance. However, the implementation of e-Procurement in DKI Jakarta is far from optimal, especially in the Jakarta provincial government agency in MRT project. E-Procurement becomes the basis for initiating transparency for many government projects. In addition, the main challenge in implementing e-Procurement's success is in terms of determining which criteria to be systematically taken during the project execution [http://www.jakartamrt.com, accessed October 9, 2016].

The aims of this study is to determine the criteria and sub-criteria of success of the implementation of MRT parts' e-Procurement, and to determine the priorities of the MRT parts' e-Procurement process for the provincial government of DKI Jakarta.

2. Literature review

2.1. e-Supply Chain Management and e-Governance

Technological innovation which is collaborated within the supply chain management (e-SCM) becomes a very important aspect to support e-Governance. In well developed countries, e-Governance has proven to increasing the efficiency and technical capacity of work process, shortening the purchasing and transaction process, and increasing the information disclosure during and after the procurement process [2]. Further, e-SCM facilities can reduce costs, increase demand and create a new business model. It is very potential in providing benefits to all stakeholders in reducing costs and improve product quality and information [3, 4]. Further, e-SCM have proven to provide real time communication amongst supply chain members, better real time forecasting decisions, and improve partnerships [5]. Stakeholders involved in policy making can help build a trust relationship between government and society, and leverage the quality of the policy. In this case, good policy could influence the sustainability of e-SCM [6]. In the long term, e-SCM is hoped to be the main driver of good e-Governance. Further, e-Governance should be the basis for leveraging internal efficiency and supporting the interfaces with citizens [7]. This is the main idea of creating good government governance.

2.2. e-Procurement

E-Procurement refers to the use of internet-based information (integrated) and communication technologies in reaching an individual or a process in the procurement activities included in search, resources, negotiations, reservations, receipts and payments [8]. E-Procurement can be considered as one of the technological solutions where an organization procures the goods via the internet [2]. In other words, e-Procurement can be explained as a technology utilization, especially internet and communication facilities, in every procurement process from the beginning to the end of the process. In term of MRT existence in DKI Jakarta, E-Procurement is considered very important because with an electronic procurement system, it will automatically improve transparency, efficiency, effectiveness, accountability, fairness and non-discrimination, open and healthy competition, interoperability, and data security assurance. Supervision is also an advantage that exists in the application of e-Procurement, because any incoming information can be monitored and filtered. In the implementation of e-Procurement in the government sector, risk analysis and future strategies for implementation on e-Government projects are required. In addition, a clear guideline may function as to reducing corruption in public procurement activities [9].

2.3. Criteria and sub-criteria of e-Procurement

E-Procurement is one of the main topics of e-Government, where many organizations need advice and guidance on using the new platform. Without these critical success criteria and sub-criteria, it is almost impossible to get the process and interpret the success of e-Procurement, especially in the public sector [7, 10]. Several criteria have been explored from various contexts to explore how e-Procurement can contribute to the success and sustainability of organizations, such as government policy and regulation [11-14, 17], top management commitment [11, 13, 15, 16], suppliers relationships [13, 18, 19], value acquisition [13, 20], and technology infrastructure [1, 21, 22]. Based on the literature study, the researchers raised the hypothesis of the criteria and sub-criteria of success in e-Procurement which is represented in the form of a supportive model to answer the questions in this study, whereas this model is limited in accordance with the reference to considerations related to the procurement of MRT parts.

The above criteria are established through several sub-criteria such as the role of central government, the participation of local government, government commitment, business owner commitment, accountability, mutual trust, price competitiveness, conformity to specification, webpage system and internet connection quality. Figure 1 represents the relationship between sub-criteria, criteria and successful e-Procurement implementation.

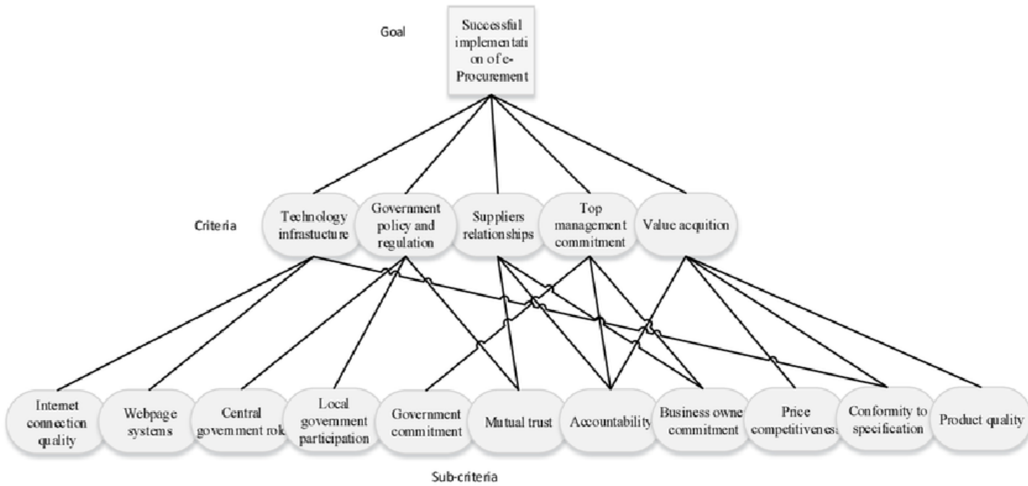

Figure 1. Sub-criteria, criteria and goal

3. Methods

By context, this research focuses on the criteria and sub-criteria related to MRT e-procurement spare part in DKI Jakarta. In addition, after determining the criteria and sub-criteria, the researchers continues the research process by weighting each criteria and sub-criteria with the Fuzzy Analytic Hierarchy Process (FAHP) [23], where data were obtained based on three experts from academic, business and government. The experts should possess the following criteria: minimum five years of experience in public transportation procurement process; and, involves in the current MRT project, as consultant, researcher and or team member. In this study, the three experts consist of Mr. Timbul F. Sitompul, Head of Administration LPSE Management Unit of DKI Jakarta Province, Mr. Tulus M. Sihombing, Researcher at STIMLOG, and Ms. Calvina Anastasia, Procurement Specialist at PT. MRT Jakarta. Each expert represents the government, academic, and business.

In the use of AHP, the results of the decisions given by the experts are not deterministic, but rather resemble linguistic perceptions. So, the use of AHP in multi-criteria decision making (MCDM) is less able to overcome the uncertainty experienced by decision makers when they are asked about the definite value in pairwise comparison [24]. In this case, the use of FAHP is more appropriate. Information in FAHP, as well as conventional AHP, employ 1 to 9 scales in the form of pairwise comparison. In addition, FAHP uses Triangular Fuzzy Number (TFN) for fuzzification of crisp comparison matrix. The fuzzification on AHP scale creates a new scale called the AHP fuzzy scale [25].

The next step is designing the questionnaires to assess each criteria and sub-criteria of e-Procurement. Data are then processed using FAHP to determine the weight of each criterion. The questionnaire uses five valuation scales: Equal Importance (EI), Moderate Importance (MI), Strong Importance (SI), Very Strong Importance (VSI), and Extreme More Importance (EMI). Each of the fuzzy rating scales has different membership functions, such as EMI (8,9,10), VSI (6,7,8), SI (4,5,6)), MI (2,3,4), and EI (1,1,2). These membership functions were used to calculate the weight of each criterion.

The initial process of fuzzy data processing was by creating matrix pairs of data. Further, three fuzzy numbers were converted into two numbers. Finally, the data were converted into one number using alpha cut method so as to get the crisp value (defuzzification process). The data were then combined from the three experts using the mean geometric method, so that the combined crisp value can be derived. In processing the data using the FAHP method, it is necessary to calculate the consistency test, where the consistency test is useful to determine whether (or not) the resulting pairwise comparisons are consistent.

The consistency measurement of pairwise comparison matrices was based on the greatest Eigen value [26]. The consistency index of "n" order matrix was obtained by the following formula:

$$CI = (\lambda maks-n) / (n-1) \quad (1)$$

Where, CI = Consistency deviation ratio (consistency index); λmax = the largest eigenvalue of the "n" order matrix; and n = order matrix. After getting the value of CI, the next step was to calculate the CR value to discover the consistency of the data being processed. The formula of calculating CR was as followed:

$$CR = CI / RI \quad (2)$$

Where, RI value was based on "n". Table 1 described several RI value based on n (1 to 10).

Table 1. RI value

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

After the fuzzy phase has completed, the next step was to allocate weights to determine the priorities of the criteria and sub-criteria [27].

4. Findings and discussions

4.1. Criteria assessment

Assessment of the importance weight of each criterion were done by three experts. There are several criterion that utilized as indicators: SIT (technology infrastructure)), RJS (suppliers relationships), DKMA (top management commitment), RK (government policy and regulation), and EN (value acquisition). The results obtained through the questionnaires were in the form of comparisons between criterions. All the results of the questionnaire were arranged in the form of a pairwise comparison matrix containing the fuzzy of numbers.

In the relative importance assessment of two elements, a reciprocal axiom means that if the element in column one is assigned 3 times more important than the element in column two, then the elements in column two should be equal to 1/3 times more important than the elements in column one. In data retrieval, researchers have made revisions after knowing pairwise comparison data were inconsistent. In this case, there was a mistake from the interpretation or distribution of opinion of each respondent or experts in interpreting the comparison on the criteria and sub-criteria so that we need to revise the weight on the criteria and sub-criteria. Pairwise Comparison Matrix between criterions obtained from three experts can be seen in Table 2-4.

Table 2. Assessment from Expert 1

	SIT			**RJS**			**DKMA**			**RK**			**EN**		
SIT	1	1	2	2	3	4	1/4	1/3	1/2	1/4	1/3	1/2	2	3	4
RJS	1/4	1/3	1/2	1	1	2	1/4	1/3	1/2	1/6	1/5	1/4	2	3	4
DKMA	2	3	4	2	3	4	1	1	2	1	1	2	2	3	4
RK	2	3	4	4	5	6	1/2	1	1	1	1	2	4	5	6
EN	1/4	1/3	1/2	1/4	1/3	1/2	1/4	1/3	1/2	1/6	1/5	1/4	1	1	2

Table 3. Assessment from Expert 2

	SIT			RJS			DKMA			RK			EN		
SIT	1	1	2	2	3	4	1/6	1/5	1/4	4	5	6	4	5	6
RJS	1/4	1/3	1/2	1	1	2	1/4	1/3	1/2	1/8	1/7	1/6	1/6	1/5	1/4
DKMA	4	5	6	2	3	4	1	1	2	1/8	1/7	1/6	4	5	6
RK	1/6	1/5	1/4	6	7	8	6	7	8	1	1	2	6	7	8
EN	1/6	1/5	1/4	4	5	6	1/6	1/5	1/4	1/8	1/7	1/6	1	1	2

Table 4. Assessment from Expert 3

	SIT			RJS			DKMA			RK			EN		
SIT	1	1	2	2	3	4	1/4	1/3	1/2	1/6	1/5	1/4	1/4	1/3	1/2
RJS	1/4	1/3	1/2	1	1	2	1/4	1/3	1/2	1	1	2	1/4	1/3	1/2
DKMA	2	3	4	2	3	4	1	1	2	2	3	4	2	3	4
RK	4	5	6	1/2	1	1	1/4	1/3	1/2	1	1	2	1	1	2
EN	2	3	4	2	3	4	1/4	1/3	1/2	1/2	1	1	1	1	2

4.2. Sub-criteria assessment

Assessment of the weight of interest of each sub-criteria was done by three experts. There were several sub-criteria that were employed as indicators: JI (internet connection quality), SWP (webpage systems), KS (conformity to specification), AK (accountability), HK (mutual trust), KPB (business owner commitment), KP (government commitment), PPP (central government role), PPD (local government participation), HT (price competitiveness), and KL (Quality). Table 5 shows the overall results of the expert assessment for sub-criteria under criterion "technology infrastructure" (sub-criteria 1) as example.

Table 5. Assessment from Expert 1 for sub-criteria 1

	JI			SWP			KS		
JI	1	1	2	1	1	2	2	3	4
SWP	1/2	1	1	1	1	2	2	3	4
KS	1/4	1/3	1/2	1/4	1/3	1/2	1	1	2

Similar steps were conducted to assess the other sub-criteria and criteria. The next step was to convert the numbers to a TFN (Triangular Fuzzy Number) scale. Fuzzy numbers are usually shown in the form of three numbers namely (l, m, u). The parameter represents the smallest possible value, the promising value, and the largest value representing the fuzzy problem. Tables 6 summarizes the converted fuzzy numbers.

Table 6. Converted assessment from Expert 1

	SIT		RJS		DKMA		RK		EN	
SIT	1.00	1.50	2.50	3.50	0.29	0.42	0.29	0.42	2.50	3.50
RJS	0.29	0.42	1.00	1.50	0.29	0.42	0.18	0.23	2.50	3.50
DKMA	2.50	3.50	2.50	3.50	1.00	1.50	1.00	1.50	2.50	3.50
RK	2.50	3.50	4.50	5.50	0.75	1.00	1.00	1.50	4.50	5.50
EN	0.29	0.42	0.29	0.42	0.29	0.42	0.18	0.23	1.00	1.50
Total	6.58	9.33	10.79	14.42	2.63	3.75	2.66	3.87	13.00	17.50

Similar steps were conducted for the assessment from Expert 2 and 3. The next step was the assessment on each sub-criteria that has been completed by the three experts and converted into two fuzzy numbers.

Before defuzzification, the assessment matrix were combined into one assessment matrix, by the following formula:

$$A_g(l,u) = \sqrt[3]{(l_1 * l_2 * l_3),(u_1 * u_2 * u_3)} \quad (3)$$

Where, $A_1 = (l_1, u1)$; $A_2 = (l_2, u2)$; $A_3 = (l_3, u3)$. From formula (3), a joint assessment matrix was formed. Table 7 summarizes the combined assessment matrix for criteria (as example). This step was also conducted for the sub-criteria.

Table 7. Combined matrix for the criteria

	SIT		RJS		DKMA		RK		EN	
SIT	1	1.5	2.50	3.50	0.25	0.34	0.62	0.80	1.49	2.00
RJS	0.29	0.42	1	1.5	0.29	0.42	0.29	0.37	0.51	0.69
DKMA	3.04	4.07	2.50	3.50	1	1.5	0.69	0.93	3.04	4.07
RK	1.27	1.63	2.80	3.46	1.12	1.46	1	1.5	3.08	3.96
EN	0.51	0.69	1.49	2.00	0.25	0.34	0.26	0.33	1	1.5
Total	6.12	8.31	10.29	13.96	2.92	4.06	2.87	3.94	9.12	12.22

The defuzzification was then utilized to convert the fuzzy values into "crisp" value (CFCS, Converting Fuzzy into Crisp Scores). The calculation of crisp value at $\alpha = 0.5$ was based on formula 4.

$$\text{Crisp Value} = 0.5*l + (1-0.5)*u \quad (4)$$

Table 8 summarizes the calculation of combined crisp value (as example).

Table 8. Combined crisp value for criteria

	SIT	RJS	DKMA	RK	EN
SIT	1	3.00	0.29	0.71	1.74
RJS	0.35	1	0.35	0.33	0.60
DKMA	3.56	3.00	1	0.81	3.56
RK	1.45	3.13	1.29	1	3.52
EN	0.60	1.74	0.29	0.30	1
Total	6.96	11.87	3.24	3.15	10.42

It is necessary to conduct consistency test to find out whether the matrix of pairs is consistent or not. The consistency test was performed by using formula (1) and (2) as the median values in the fuzzy matrix (Table 9). The limit value of CR is 0.1 for matrix bigger than 4x4[26].

Table 9. Eigen value computation for all criterion

	SIT	RJS	DKMA	RK	EN	Eigen Vector	Rank
SIT	0.14	0.25	0.09	0.23	0.17	0.176	3
RJS	0.05	0.08	0.11	0.11	0.06	0.082	5
DKMA	0.51	0.25	0.31	0.26	0.34	0.334	1
RK	0.21	0.26	0.40	0.32	0.34	0.305	2
EN	0.09	0.15	0.09	0.09	0.10	0.103	4

In addition, consistency test results show that all matched matrix combined in this study were consistent with CR ≤ 0.1. Consistency test is very important because the reliability of a study is also considered from the reliability of data used as a source in subsequent processing. In this case, consistency test has an important role in showing the reliability of data from the research results obtained. Table 10 summarizes the consistency test for criteria and sub-criteria.

Table 10. Consistency test for all criterion

	λmax	C.I.	R.I.	C.R.	Note
Criteria	5.310	0.077	1.120	0.069	Consistent
Criterion 1	3.075	0.037	0.580	0.064	Consistent
Criterion 2	3.057	0.028	0.580	0.049	Consistent
Criterion 3	3.095	0.047	0.580	0.082	Consistent
Criterion 4	3.087	0.044	0.580	0.075	Consistent
Criterion 5	4.213	0.071	0.900	0.071	Consistent

Crisp values for the criteria and sub-criteria become the starting point in calculating the weight of each criterion or sub-criteria. In performing weight calculations, researchers use Microsoft Excel in the calculation process. Weight calculation was conducted by normalizing the crisp value on criteria and sub-criteria. Table 11 shows the AHP weight calculation (as example).

Table 11. Weight index for criteria

	SIT	RJS	DKMA	RK	EN	Weight	Rank
SIT	0.14	0.25	0.09	0.23	0.17	0.176	3
RJS	0.05	0.08	0.11	0.11	0.06	0.082	5
DKMA	0.51	0.25	0.31	0.26	0.34	0.334	1
RK	0.21	0.26	0.40	0.32	0.34	0.305	2
EN	0.09	0.15	0.09	0.09	0.12	0.103	4

Table 12. Recapitulation of AHP weight index

Criteria	Weight	Sub-criteria	Weight	Final weight
SIT	0.176	**JI**	0.554	0.097
		SWP	0.278	0.049
		KS	0.168	0.029
RJS	0.082	**AK**	0.555	0.045
		HK	0.171	0.014
		KPB	0.274	0.022
DKMA	0.334	**AK**	0.435	0.145
		KPB	0.186	0.062
		KP	0.379	0.127
RK	0.305	**HK**	0.137	0.042
		PPP	0.625	0.191
		PPD	0.239	0.073
EN	0.103	**AK**	0.323	0.033
		HT	0.197	0.020
		KS	0.265	0.027
		KL	0.215	0.022

Table 12 summarizes the recapitulation of the weighting criteria and sub-criteria along with the final weighting which is the multiplication of the weight of the criterion by the weight of each sub-criterion. The table summarizes all the rank for criteria in MRT spare parts e-procurement: top management commitment, government policy and regulation, technology infrastructure, value acquisition, and suppliers' relationships.

5. Conclusion

The FAHP computation results show that the criterion of top management commitment has the greatest importance weight by 0.334, followed by government policy and regulation (0.305), technology infrastructure (0.176), value acquisition (0.103), and suppliers' relations (0.082). Each criterion should focus on certain sub-criteria. In the MRT e-Procurement case, technology infrastructure should focus on internet connection quality, followed by webpage systems, and the effort to meet the conformity to required specification. For the second criterion, the sequence of focus should be building accountability, creating mutual trust relationships, and developing business owners' commitment. The third criterion should pay attention to accountability, commitment from business owners, and commitment from the government. As for the fourth criterion should focus on building mutual trust, exploiting central government role, and engaging the participation of local government. The value acquisition criterion should focus on building accountability of each stakeholder, maintaining price competitiveness, conform to specification of materials and product, and make sure of the product and service quality.

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