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ANALYSIS FUZZY AHP FOR OPTIMIZATION CONTRACTOR SELECTION USING MULTI-CRITERIA IN DETERMINING THE BEST ALTERNATIVE CONTRACTOR

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Abstract: Using inappropriate criteria in contractor's selection can lead to the failure of a construction project. This study aims to provide an optimal solution for contractor selection using multi-criteria. The criteria were obtained from previous research and concluded in the Focus Group Discussion. The analytical method used is Fuzzy-AHP, involving 14 experts who are registered contractors in the Company who have good performance and the contractor selection process involves a Tender Committee consisting of 5 appointed employees. The conclusion of this study shows that the criteria and weights that can be used for contractor selection are 35% bid, 22% technical ability, 13% financial ability, 11% reputation, 10% management ability and the last safety management with a weight of 9%. Each criterion has sub-criteria indicators with a total of 41 sub-criteria. Result of the consistency ratio below 10%. The conclusion contractor selection analysis using multi-criteria can screen the best contractor.

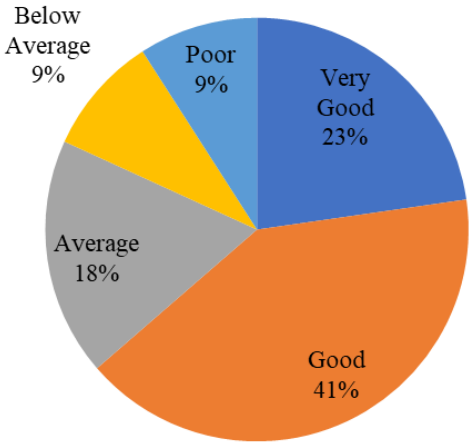
Keywords: Contractor Selection, Multicriteria Decision Making, Fuzzy-AHP, Project Procurement, Project Management.

INTRODUCTION

Contractor selection has very important role in a construction project. Selection of contractors who have the appropriate skills will improve the performance of a construction project, reduce costs according to budget, controlled schedule, and appropriate quality. A good contractor selection process is usually able to detect the contractor's ability from various aspects, such as financial ability, experience running a project, experts owned, project equipment owned and so on. In this case the use of contractor selection criteria is very helpful in making decisions. If the criteria are wrong, the selected contractor may not meet the needs, even though the decision-making process is carried out in the right way.

This research was conducted at PT. TSI, a company engaged in Hospitality sector with its head office in the Jakarta. During the period from 2016 to 2020, there were several projects construction was controlled and financed by the company. Project construction

involved 22 Contractors. Based on the performance appraisal data conducted by the project management team and the Project Committee, the data is shown in Figure 1.1 Contractor performance evaluation result during 2016 to 2020, based on each category.



Picture 1. Conctractor's evaluation chart period 2016 – 2020

source: Data of Research

Figure 1 shows that there are still contractors who get sufficient, poor, and very poor ratings if the total is 38% of the 22 contractors or as many as 8 contractors. The contractor's performance appraisal process is carried out when the contractor has carried out activities according to the agreed contract. To ensure that the next project involves contractors who can meet the Company's expectations, the use of the right criteria when selecting contractors is one way that the tender team or the Procurement Project can do.

According to previous research on contractor selection as conducted by (Araújo et al, 2018), it is considered that using multi-criteria in contractor selection can solve contractor performance problems. The multi-criteria in the selection of contractors in question are price, financial capability, safety management, similar project experience, technical team capability. Meanwhile, based on research conducted by (Sandika P. and Patradhiani P., 2019) stated that a way to solve multi-criteria problems in making decisions on the selection of construction contractors can use the AHP method. Based on the background of the problems faced by PT.TSI, a research was conducted to formulate the right criteria in the selection of contractors and using FUZZY-AHP method as a method to provide optimal solutions in determining the best alternative contractor.

LITERATURE REVIEW

The achievement of important tasks or goals in an organization or company can be done by utilizing the use of projects. Companies are now realizing that the entire business, including most routine activities, can be thought of as a series of projects. The basic purpose of starting a project is to achieve a specific goal. The reason for organizing tasks as projects is to focus the

responsibility and authority in achieving goals on individuals or small groups, (Meredith, 2009:12). Today's executives have a much better understanding and appreciation for project management than their predecessors. Initially, project management was seen only as project scheduling and later managing projects using network-based software.

Project Management

According to (Kerzner, 2014:1) Project management has evolved from a series of processes that were once considered "good" to a structured methodology that is considered mandatory for the survival of the company. Project management is now considered a project management process and a business process. Therefore, project managers are expected to make business decisions as well as project decisions. Understanding project management according to (Kerzner, 2017:4) Project management is planning, organizing, leading, and controlling company resources to achieve predetermined short-term goals. Furthermore, project management uses a vertical and horizontal hierarchical approach.

Project Procurement Management

As explained in PMBOK 5th edition, Procurement in project management which includes the processes needed to carry out the process of purchasing or obtaining products, services / services obtained from outside the project. The procurement management process includes the management and supervision processes needed to develop and manage agreements such as contracts, purchase orders, tender processes, contractor selection, progress monitoring, until the project is completed. In the construction sector, the project procurement function is closely related to contractors and has an important role in the contractor selection process.

Contractor

A contractor is an entity that can be an individual or a company that provides products or services with skilled labor, consulting or specially designed and manufactured equipment, components, or systems. (Nicholas ,2020:400). Contractors usually have better skills and experience and can provide a higher quality product. However, they are often not motivated by the same factors as part of the project team, such as working to the agreed time, quality work according to the submitted design, and working under budget, all of which involve the importance of the active role of the project management team in conducting performance appraisals and updating the criteria in the selection in order to get a contractor that matches the company's expectations and can work on the project according to the target set.

Criteria of selection

In selecting a contractor, it is basically the same as choosing a supplier. According to Heizer et al (2017:514) Selecting a supplier from the many candidates can be a formidable task. Selecting a supplier based solely on the lowest bid has become a rather rare approach. Various factors, sometimes competing, often play a role in decision making. Buyers may consider supplier characteristics such as product quality, delivery speed, delivery reliability, customer service, and financial performance.

In the selection of contractors, a wider assessment parameter is needed so that the selected contractor can work on the project as part of the company's important tasks. In addition to offering competitive prices (Prasetia and Imaroh, 2020), (Aptekin, 2017), other criteria are grouped into five categories as done by previous researchers (Naji, 2015) and (Taylan, 2017) the grouping is as follows:

1) Financial position, in this category includes financial stability, credit rating, working capital, turnover and equity
2) Management capabilities, in this category includes previous performance and quality, quality control policies, quality management systems, project management systems, administrative personnel experience, management knowledge, project delivery methods and locations.
3) Technical capability, in this category includes plant and equipment, personnel, level of technology use, area of expertise, integrity, project size, experience of technical personnel and workload.
4) Reputation, this category includes company age, certification or award, company achievements, unlawful activities, disqualification status, past failures in completed projects, construction quality in previous projects.
5) Health and safety. This category includes accident track records, health and safety management systems and insurance policies (Kog and Yaman, 2014b).

Decision-making

Experts provide an understanding of decisions according to their point of view and background of thought. According to (James A.F. Stoner, 1968), a decision is a choice among various alternatives. This definition contains three meanings, namely: (1) there is a choice on the basis of logic or consideration; (2) there are several alternatives to choose the best one; and (3) there is a goal to be achieved and the decision is getting closer to that goal. Based on this understanding, it can be concluded that decision making is a process of selecting the best alternative from several alternatives systematically to be followed up (used) as a way of solving problems.

Multi Criteria Decision Making (MCDM)

Multi Criteria Decision Making is one method that helps the decision-making process that has many criteria. According to (Mulliner et al, 2016), Multi Criteria Decision Making is a set of methods related to evaluating a series of alternatives that have many, often conflicting, and various criteria. The purpose of Multi Criteria Decision Making is to provide choices, ratings, descriptions, classifications, groupings, and to sort alternatives from the most preferred to the least preferred options. There are three stages followed by all Multi Criteria Decision Making methods:

1) Determine relevant criteria and alternatives;
2) Attach a numerical measure of the relative importance of the criteria and the impact on alternatives to those criteria.

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a decision support method developed by an Iraqi-born professor of mathematics at the University of Pittsburgh, Thomas L. Saaty. According to (saaty and Vargas, 2001:1). Analytic Hierarchy Process (AHP) is designed to overcome the rational and intuitive to choose the best from several alternatives that are evaluated with respect to several criteria. In this process, the decision maker performs a simple pairwise comparison assessment which is then used to develop overall priorities to rank alternative priorities. The use of the importance level scale refers to the scale compiled by Saaty, which can be seen in Table 2.1.

Table 1. The scale of each level of importance.

No	Description	AHP Scale
1	Extreme preference	9
2	Very strong preference	7
3	Strong preference	5
4	Medium preference	3
5	Same preference	1
6	Medium lower	1/3
7	Strong lower	1/5
8	Very strong lower	1/7
9	Extreme lower preference	1/9

Source: Plebankiewicz and Kubek (2015)

Fuzzy AHP

The Analytical Hierarchical Process (AHP) combined with fuzzy set theory or called F-AHP was introduced by Zadeh, (1996) has been widely used in the Multi-Criteria Decision Making (MCDM) process where fuzzy numbers are used to represent human judgments more realistically. Over the past few decades, many articles have been published proposing algorithms through which priority vectors (or weight vectors) can be computed from fuzzy comparison matrices. To effectively deal with subjective and ambiguous perceptions, fuzzy numbers are integrated with AHP, enabling the expression of appropriate linguistic evaluations (Calabrese et al., 2016).

RESEARCH METHODS

This research uses a quantitative approach, quantifying the importance and weight of each criterion to obtain the best criteria that can be used in contractor selection. The design of this research is descriptive exploratory, which aims to describe efforts to collect information systematically and measurably to determine the right contractor selection criteria.

The criterion is based on references from previous research and Focus Group Discussions (FGD) involving PT.TSI Management, Project Teams, Engineering, Finance, Consultants, and several Contractor representatives registered at PT.TSI, followed by the data collection process. Data collection method using a questionnaire given to 14 contractors registered at PT. TSI. Other data used in this study are secondary data

originating from the company's internal reports, previous research data, and supporting data needed when selecting contractors, all of which are already available in the company archives. The analytical method in this study uses Fuzzy-AHP for the ranking calculation process, which is a combination of the Fuzzy method and the AHP method. Procedure of this research is explained as below sequence:

1) The criteria based on literature references, previous research, and finalized in Focus Group Discussion (FGD). Paired questionnaires were made and sent to 14 experts and then tested using AHP to get priority weights, test the consistency of assessments from the experts. Some of formula mathematic is used in this stage:
   - Geometric Mean:

   $G = (X1\ x\ X2\ x\ ..Xn)^{1/n}$ ..... (1)

   Annotations:

   G = Geometric mean; X1 = sequence data 1; n = no of data
   - Eigen vector

   $\frac{Vector\ Value}{\sum Vector\ Value}$ ..... (2)
   - λ max:

   $\lambda\, maks = \frac{\sum x}{n}$ ..... (3)
   - Consistency Index

   $CI = \frac{\lambda\,\text{maks} - n}{n-1}$ ..... (4)

   Annotations: CI = Consistency Index, n = no of criteria
   - Consistency Ratio

   $CR = \frac{CI}{RI}$ ..... (5)

   Annotations: RI = AHP Index Ratio as in Table 3.2.

Table 2 *Random Indeks* (RI)

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
RI	0,00	0,00	0,58	0,90	1,12	1,12	1,24	1,32	1,41	1,45	1,49	1,48	1,56

Source: Saaty (1996)

2) If there is a failure in the criteria testing process, the process returns to the criteria formulation stage, and the questionnaire is re-circulated.
3) If the results of the criteria test are acceptable, the next process is to analyze the contractor selection using the Fuzzy-AHP method, to find out the best contractor. To evaluate Fuzzy Synthetic extend using this formula:

$Si = \sum_{j=1}^{m} M_{gi}^{j}\,\text{x}\,\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]$ .....(6)

remarks: $\sum_{j=1}^{m} M_{gi}^{j} = \sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj\ , \sum_{j=1}^{m} uj$

And $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right] = \frac{1}{\sum_{j=1}^{m} uj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} lj}$

Annotation:

Si	= Fuzzy Synthetics extend
M	= Triangular Fuzzy Number
I	= Index each row
J	= Index
$\sum_j^m M_{gi}^j$	= Total value each column starting index 1 each row.
$\sum_{j=1}^n lj$	= Total value 1 each 1st column (lower)
$\sum_{j=1}^n mj$	= Total value 1 each 1st column (median)
$\sum_{j=1}^n uj$	= Total value 1 each 1st column (upper)

4) The draft criteria can be used as recommendations for management for the contractor selection process in the next tender package.

FINDINGS AND DISSCUSSION

The study was conducted from November 2020 to March 2021. Draft criteria for contractor selection criteria were determined based on the summary of previous researchers Alptekin, (2017), Prasetia and Imaroh (2020), Naji (2015), Aulady (2016), Taylan et al (2017), Karakhan (2018), Archeamfour et al (2019) followed by a Focus Group Discussion (FGD) involving the management of PT. TSI, Project Team, Engineering, Finance, Consultants, and several Contractor representatives registered with PT. TSI which consists of 6 Main Criteria and 41 Sub-criteria. Each criterion is coded to facilitate the analysis process in the next stage and converted to paired questionnaire form. Paired questionnaires between criteria by providing columns of importance from numbers 1 to 9 distributed to 14 (fourteen) respondents who are registered contractors.

Geometric mean of the questionnaire

Paired questionnaire data received from respondents were summarized and processed using Microsoft Excel program. The data received from each respondent is made into a table in one worksheet. The recording of the questionnaire table includes the number, name, company, position, length of service and assessment data.

Data collected from the respondents is still in the form of ordinal data, only showing the level of importance of the paired questionnaire, to be able to calculate the geometric average with formula no (1), the data is first converted into Decimal form using the scale in Table 2.1. The following is a display of the geometric mean in Table 4.3.

Table 3 Geometric Mean

Code of Criteria	1	2	3	.	.	.	12	13	14	Code of Criteria	Geometric Mean
P	7,00	7,00	5,00	.	.	.	5,00	5,00	3,00	F	2,85
P	5,00	3,00	0,20	.	.	.	7,00	5,00	0,20	T	2,73
P	5,00	5,00	5,00	.	.	.	7,00	7,00	5,00	M	3,21
P	3,00	3,00	7,00	.	.	.	5,00	7,00	7,00	R	3,43
P	5,00	5,00	5,00	.	.	.	7,00	5,00	5,00	S	2,36
.											
.											

.

S3	1,00	3,00	9,00	9,00	0,11	0,11	S4	0,88
S3	1,00	0,14	9,00	7,00	7,00	7,00	S5	1,81
S4	1,00	0,14	9,00	9,00	5,00	9,00	S5	1,11

Source: Data of Research

The geometric mean of all 14 respondents was calculated for all comparison criteria ranging from the main criteria to the safety management criteria. Considering that there are quite a lot of data, the data shown in Table 4.3 is only partially as an illustration.

Paired matrix of Criteria

Compile a paired matrix using the geometric mean data for all criteria levels. Table 4.3 shows an overview of the paired matrix for the Main Criteria.

Table 4 Paired matrix of main criteria

Code of Criteria	P	F	T	M	R	S
P	1,00	2,85	2,73	3,21	3,43	2,36
F	0,35	1,00	1,11	1,24	0,84	1,05
T	0,37	0,90	1,00	2,23	3,33	3,78
M	0,31	0,81	0,45	1,00	0,93	1,48
R	0,29	1,19	0,30	1,08	1,00	1,45
S	0,42	0,95	0,26	0,68	0,69	1,00
Total	**2,74**	**7,70**	**5,85**	**9,43**	**10,22**	**11,12**

Source: Data of Research

Using same procedure, the creation of a paired matrix based on the geomean average data and for reciprocity using the formula 1/ (x, y) where x, y is the value of the coordinates in a matrix.

Explanation of filling in the th Row and Column Matrix 1 (P, P):

- Matrix PP = 1
- Matrix PF = 2,85, and Matrix FP = 1/PF = 1 / 2,85 = 0,35.
- Matrix PT = 2,73, and Matrix TP = 1/PT = 1 / 2,73 = 0,37.
- Matrix PM = 3,21, and Matrix MP= 1/PM= 1 / 3,21 = 0,31.
- Matrix PR = 3,43, and Matrix RP = 1/PR = 1 / 3,43 = 0,29.
- Matrix PS = 2,36 and Matrix SP = 1/PS = 1 / 2,36 = 0,42.

The same procedure is carried out for the next row and column Matrix until all the Matrix is filled.

Eigenvectors and priority vectors

Continued with priority vector calculations by doing eigenvector calculations. The eigenvectors shown in Table 5

Table 5 Eigenvectors and priority vectors of main criteria

Code	P	F	T	M	R	S	Priority Vectors

P	0,36	0,37	0,47	0,34	0,34	0,21	0,35
F	0,13	0,13	0,19	0,13	0,08	0,09	0,13
T	0,13	0,12	0,17	0,24	0,33	0,34	0,22
M	0,11	0,11	0,08	0,11	0,09	0,13	0,10
R	0,11	0,15	0,05	0,11	0,10	0,13	0,11
S	0,15	0,12	0,05	0,07	0,07	0,09	0,09
Total	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**

Source: Data of Research

Calculations using formula (2) show the following results:

- Matrix P, P = 1 / 2,74 = 0,36
- Matrix F, P = 0,35 / 2,74 = 0,13
- Matrix T, P = 0,37 / 2,74 = 0,13
- Matrix M, P = 0,31 / 2,74 = 0,11
- Matrix R, P = 0,29 / 2,74 = 0,11
- Matrix S, P = 0,42 / 2,74 = 0,15

The same procedure is calculated for other Matrix so that the eigenvalues for all Matrixs are filled. Table 4.4 also shows the priority vectors for the main Criteria. The weight of each criterion is calculated using the formula $VP_p = \sum(v1, v2 \ldots vn)/\sum n$ (7), Example of the calculation of the priority vector of the Main Criteria row P in Table 4.7, the total criteria = 6:

$VP_p = \sum(0{,}36; 0{,}37; 0{,}47; 0{,}34; 0{,}34; 0{,}21)/6$ = 0,35 atau 35%, same formula (7) is used to caclculate priority vector for next row.

Consistency Ratio

Perform consistency test on each pairwise comparison Matrix. If CR <= 10%, then the Matrix is consistent.

Table 6 Consistency Ratio

No	Criteria	Indeks	N	λ maks	CI	RI	CR	Remarks
1	Main Criteria	KU	6	6,34	0,07	1,24	5%	Acceptable
2	Sub-Criteria: Bid	P	4	4,16	0,05	0,90	6%	Acceptable
3	Sub-Criteria: Financial	F	7	7,63	0,11	1,32	8%	Acceptable
4	Sub-Criteria: Technical	T	8	8,24	0,03	1,41	2%	Acceptable
5	Sub-Criteria: Management	M	11	12,16	0,12	1,51	8%	Acceptable
6	Sub-Criteria: Reputation	R	6	6,40	0,08	1,24	6%	Acceptable
7	Sub-Criteria: Safety Management	S	5	5,09	0,02	1,12	8%	Acceptable

Source: Data of Research

Table 4.5 is the consistency test table with the consistency test formula with the formula (4), the consistency index with the formula (5), and the Random Index according to Table 3.2. The following are the details of the calculation of the consistency ratio test:

- CI Criteria KU= $\frac{6{,}34-6}{6-1}$ = 0,07, and CR = 0,07/1,24 = 5%, *Acceptable*.

- CI sub-Criteria P=$\frac{4,16-4}{4-1}$ = 0,05, and CR = 0,05/0,90 = 6%, *Acceptable*.
- CI sub-Criteria F=$\frac{7,63-7}{7-1}$ = 0,11, and CR = 0,11/1,32 = 8%, *Acceptable*.
- CI sub-Criteria T=$\frac{8,24-8}{8-1}$ = 0,03, and CR = 0,03/1,41 = 2%, *Acceptable*.
- CI sub-Criteria M=$\frac{12,16-11}{11-1}$ = 0,12, and CR = 0,12/1,51 = 8%, *Acceptable*.
- CI sub-Criteria R=$\frac{6,4-6}{6-1}$ = 0,08, and CR = 0,08/1,24 = 6%, *Acceptable.*
- CI sub-Criteria S=$\frac{5,09-5}{5-1}$ = 0,02, and CR = 0,02/1,12 = 8%, *Acceptable.*

Based on the calculation results of all criteria and sub-criteria, it is known that all pairwise comparison matrices have a CR below 10%, this means that the expert's assessment of the importance of multi-criteria is acceptable.

Contractor selection analysis

After knowing the priority weights and the consistency test results have been accepted, then implement the Criteria in the contractor selection process using Fuzzy AHP. The contractor selection analysis was carried out using data from the Architect Structure and Plumbing work package. Restaurant construction projects owned by the company were in the region. Analysis of the determination of contractors is carried out at the final stage of the tender. When the 3 best contractors are left, they are coded K01, K02 and K03. The tender process is carried out by a tender committee consisting of 5 members consisting of appointed employees and project consultant representatives with codes C01, C02, C03, C04 and C05.

Fuzzification of AHP scale into Triangular fuzy number (TFN)

The process is almost like AHP, for all Criteria formulations, paired questionnaires are made to measure the level of importance of each contractor candidate for each Criteria and distributed to committee members. After the data is collected, the assessment results are converted into fuzzy numbers in the form of decimal numbers, as described in Table 4.6.

Table 7 Fuzzifikasi skala AHP

Code of Criteria	AHP Scale											Fuzzification			
	Contractor	9	7	5	3	1	3	5	7	9	Contractor	AHP Value	*l*	*m*	*u*
P1	K01									X	K02	0,11	0,11	0,11	0,14
	K01	X									K03	9,00	7,00	9,00	9,00
	K02	X									K03	9,00	7,00	9,00	9,00
P2	K01							X			K02	0,20	0,14	0,20	0,33
	K01			X							K03	5,00	2,00	5,00	7,00
	K02		X								K03	7,00	5,00	7,00	9,00
⋮															
S4	K01			X							K02	5,00	2,00	5,00	7,00
	K01				X						K03	3,00	1,00	3,00	5,00
	K02								X		K03	0,14	0,11	0,14	0,20
S5	K01				X						K02	3,00	1,00	3,00	5,00
	K01			X							K03	5,00	2,00	5,00	7,00
	K02							X			K03	0,20	0,14	0,20	0,33

Source: Data of Research

Fuzzification of the AHP scale using the reference conversion table from wu et al (2009); Liou, J. J., & Chuang, M. L. (2008), and Anshori, (2012) as shown at Table 8.

Table 8 Comparison of interests between 2 variables

No	Linguistic variable	AHP Scale	Fuzzy Scale (TFN)	Reciprocal TFN
1	Extreme preference	1	(1 , 1, 1) = (1 , 1 , 3)	(1 , 1, 1) = (1/3 , 1 , 1)
2	Very strong preference	3	(1 , 3 , 5)	(1/5 , 1/3 , 1/1)
3	Strong preference	5	(3 , 5 , 7)	(1/7 , 1/5 , 1/3)
4	Medium preference	7	(5 , 7 , 9)	(1/9 , 1/7 , 1/5)
5	Same preference	9	(7 , 9 , 9)	(1/9 , 1/9, 1/7)
6	Middle each scale	2,4,6,8	(x-2, x , x+2)	(1/(x+2), 1/x, 2/(x-2)

Source: wu et al (2009); Liou, J. J., & Chuang, M. L. (2008), and Anshori, (2012)

Geometric mean of TFN

Perform the calculation of the geometric mean of the fuzzy numbers for each criterion from the results of the assessment of all members of the tender committee. The formula used (1) for each fuzzy number, Table 4.8 shows a partial description of the results of the calculation of the geometric mean of the fuzzy number criteria against the comparison between each contractor.

Table 9 Geometric Mean TFN

		C01				C05				Geometric Mean		
Code Criteria	Contractor	*l*	*m*	*u*	. . .	*l*	*m*	*u*	Contractor	*l*	*m*	*u*
P1	K01	0,11	0,11	0,14		0,11	0,14	0,20	K02	0,12	0,14	0,19
	K01	7,00	9,00	9,00		5,00	7,00	9,00	K03	3,97	6,77	8,14
	K02	7,00	9,00	9,00		7,00	9,00	9,00	K03	6,12	8,14	9,00
P2	K01	0,14	0,20	0,33		0,11	0,11	0,14	K02	0,12	0,14	0,19
	K01	2,00	5,00	7,00		7,00	9,00	9,00	K03	5,45	8,00	8,56
	K02	5,00	7,00	9,00		5,00	7,00	9,00	K03	4,16	6,54	8,56
.												
.												
.												
S4	K01	2,00	5,00	7,00		2,00	5,00	7,00	K02	2,00	5,00	7,00
	K01	1,00	3,00	5,00		5,00	7,00	9,00	K03	3,62	5,91	8,00
	K02	0,11	0,14	0,20		0,11	0,14	0,20	K03	0,11	0,14	0,20
S5	K01	1,00	3,00	5,00		5,00	7,00	9,00	K02	4,15	6,53	8,00
	K01	2,00	5,00	7,00		2,00	5,00	7,00	K03	2,00	5,00	7,00
	K02	0,14	0,20	0,33		0,14	0,20	0,33	K03	0,14	0,20	0,33

Source: Data of Research

Example of calculation Geometric mean using formula (1) for criteria P1 row K01-K02 (first row in Table 4.8. as below:

$l = (l_{C01}\text{x}l_{C02}\text{x}l_{C03}\text{x}l_{C04}\text{x}l_{C05})^{1/n} = (0{,}11x0{,}11x0{,}11x0{,}14x0{,}11)^{1/5} = 0{,}12$

$m = (m_{C01}\text{x}m_{C02}\text{x}m_{C03}\text{x}m_{C04}\text{x}m_{C05})^{1/n} = (0{,}11x0{,}11x0{,}14x0{,}20x0{,}14)^{1/5} = 0{,}14$

$u = (u_{C01} x u_{C02} x u_{C03} x u_{C04} x u_{C05})^{1/n} = (0{,}14x0{,}14x0{,}20x0{,}33x0{,}20)^{1/5} = 0{,}19$

In the same way, the calculation is carried out on all criteria until all rows of the matrix are filled with the geometric mean value.

Create a paired matrix and summary TFN

Based on the geometric mean data, followed by the creation of a paired matrix and the summation of each fuzzy number. Table 4.9 displays the paired Matrix of the contractor's assessment of each criterion. To make it easier to understand the process of making paired Matrixs, the following is an explanation of paired Matrixs for Criteria P1 (Competitive price) from each contractor (K01, K02, K03):

- K1, K1 = (1.00, 1.00, 1.00) = Reciprocal K1, K1= (1.00, 1.00, 1.00)
- K1, K2 = (0.12, 0.14, 0.19) = Reciprocal K2, K1 = (1/0.19, 1/0.14, 1/0.12)
- K1, K3 = (3.97, 6.77, 8.14) = Reciprocal K3, K1 = (1/8.14, 1/6.77, 1/3.97)

The same process is carried out until the Criteria S5 (Safety Plan / K3 Plan). Each row of the Matrix is summed with the following formula: (l"$_1$ ", m"$_1$ ", u"$_1$ ") + (l_2 , m_2 , u_2) = (l"$_1$ +" l_2 ,m"$_1$ +" m_2 ,u"$_1$ +" u_2). Below is explanation of summary row of criteria P1 (Price competitive) against Contraktor K1:

∑P1, K1 = (l_k01+l_k02+l_k03, m_k01+m_k02+m_k03, u_k01+u_k02+u_k03)
= (1.00+0.12+3.97, 1.00+0.14+6.77, 1.00+0.19+8.14)
= (5.08, 7.90, 9.33)

Same procedure continued until Criteria S5 (Safety Plan)

∑S5, K3 = (0.14+3.00+1.00, 0.2+5.00+1.00, 0.5+7.00+1.00)
= (4.14, 6.2, 8.5)

Table 10 Paired Matrix and Total TFN

Code Criteria	Contractor	Matrix TFN									Total TFN		
		K01			K02			K03					
		l	m	u	l	m	u	l	m	u	l	m	u
P1	K01	1,00	1,00	1,00	0,12	0,14	0,19	3,97	6,77	8,14	5,08	7,90	9,33
	K02	5,16	7,24	8,56	1,00	1,00	1,00	6,12	8,14	9,00	12,28	16,38	18,56
	K03	0,12	0,15	0,25	0,11	0,12	0,16	1,00	1,00	1,00	1,23	1,27	1,42
P2	K01	1,00	1,00	1,00	0,12	0,14	0,19	5,45	8,00	8,56	6,57	9,14	9,75
	K02	5,16	7,24	8,56	1,00	1,00	1,00	4,16	6,54	8,56	10,33	14,78	18,12
	K03	0,12	0,12	0,18	0,12	0,15	0,24	1,00	1,00	1,00	1,23	1,28	1,42
.													
.													
.													
S4	K01	1,00	1,00	1,00	2,00	5,00	7,00	3,62	5,91	8,00	6,62	11,91	16,00
	K02	0,14	0,20	0,50	1,00	1,00	1,00	0,11	0,14	0,20	1,25	1,34	1,70
	K03	0,12	0,17	0,28	5,00	7,00	9,00	1,00	1,00	1,00	6,12	8,17	10,28
S5	K01	1,00	1,00	1,00	4,15	6,53	8,00	2,00	5,00	7,00	7,15	12,53	16,00
	K02	0,12	0,15	0,24	1,00	1,00	1,00	0,14	0,20	0,33	1,27	1,35	1,57
	K03	0,14	0,20	0,50	3,00	5,00	7,00	1,00	1,00	1,00	4,14	6,20	8,50

Source: Data of Research

Fuzzy synthetic extents, TFN Normalization and TFN Vector

The value of fuzzy synthetic extent is determined for each Criteria and sub Criteria. The fuzzy synthetic extent value is used to obtain the expansion of an object, so that the extent analysis value can be obtained which can be done by formula (6) with a note that the numbers used are triangular fuzzy numbers. With the extent analysis method for the value of the synthesis of pairwise comparisons of Fuzzy AHP. In Table 4.10, the results of the Fuzzy Synthesis calculation formula (6), TFN (2) normalization and TFN priority vector (7) from each criterion against each contractor are described. Calculates the vector average to return the Non fuzzy value. The last step is the normalization of the priority vector. Based on the TFN summation data that has been done for each Criteria and Sub-Criteria.

Table 11 Fuzzy synthetic extents, TFN Normalization and TFN Vector

Code Criteria	Contractor	Total TFN			Fuzzy synthetic extent			Normalization TFN	Priority vector
		l	m	u	l	m	u		
P1	K01	5,08	7,90	9,33	0,17	0,31	0,50	0,33	0,31
	K02	12,28	16,38	18,56	0,42	0,64	1,00	0,69	0,64
	K03	1,23	1,27	1,42	0,04	0,05	0,08	0,06	0,05
P2	K01	6,57	9,14	9,75	0,22	0,36	0,54	0,37	0,35
	K02	10,33	14,78	18,12	0,35	0,59	1,00	0,65	0,60
	K03	1,23	1,28	1,42	0,04	0,05	0,08	0,06	0,05
.									
.									
.									
S4	K01	6,62	11,91	16,00	0,24	0,56	1,14	0,65	0,55
	K02	1,25	1,34	1,70	0,04	0,06	0,12	0,08	0,07
	K03	6,12	8,17	10,28	0,22	0,38	0,73	0,44	0,38
S5	K01	7,15	12,53	16,00	0,27	0,62	1,27	0,72	0,61
	K02	1,27	1,35	1,57	0,05	0,07	0,13	0,08	0,07
	K03	4,14	6,20	8,50	0,16	0,31	0,68	0,38	0,32

Source: Data of Research

Fuzzy Synthetics decision

The last step is to determine the best contractor, indicated by the fuzzy Synthetics decision, which is the sum of the multiplication results between the alternative fuzzy performance values of each criterion and the weight of the criteria. Calculation data for determining the best contractor can be seen in Table 4.11.

Table 12 Fuzzy synthetic decision

Total Score					Priority Vector		
Code	Criteria	Code	Sub-criteria	Weight Criteria	K1	K2	K3
P	Bid	P1	Competitive Price	0,06	0,31	0,64	0,05
		P2	Price consistency	0,07	0,35	0,60	0,05

		P3	Term of payment	0,12	0,57	0,38	0,05
		P4	Break down price	0,09	0,52	0,42	0,06
F	Financial	F1	Limit credit facility	0,01	0,30	0,06	0,64
		F2	Financial status	0,01	0,37	0,05	0,58
		F3	outstanding loan	0,01	0,38	0,06	0,56
		F4	Available fund	0,03	0,31	0,05	0,64
		F5	Financial stability	0,03	0,29	0,05	0,66
		F6	Cash flow	0,03	0,29	0,05	0,66
		F7	Financial capacity	0,01	0,31	0,05	0,64
T	Technical	T1	Work performance	0,01	0,64	0,06	0,30
		T2	Quality management	0,02	0,57	0,06	0,36

Table 13 Fuzzy synthetic decision (continued)

Total Score							**Priority Vector**
Code	**Criteria**	**Code**	**Sub-criteria**	**Weight Criteria**	**K1**	**K2**	**K3**
		T3	Procurement management	0,03	0,65	0,06	0,29
		T4	Working schedule	0,02	0,69	0,08	0,22
		T5	Owned equipment	0,03	0,68	0,09	0,23
		T6	Expert and qualification	0,05	0,63	0,06	0,30
		T7	Working capacity	0,03	0,68	0,09	0,23
		T8	Expert certification	0,02	0,57	0,05	0,38
M	Management	M1	Previous work performance	0,01	0,59	0,06	0,35
		M2	PMO experience	0,01	0,52	0,05	0,43
		M3	Managerial level	0,01	0,57	0,07	0,36
		M4	Qualification managerial level	0,01	0,51	0,07	0,42
		M5	Accumulation project amount	0,01	0,36	0,06	0,58
		M6	Working on schedule	0,01	0,54	0,07	0,39
		M7	Working on budget	0,02	0,28	0,65	0,06
		M8	Team experience	0,02	0,36	0,06	0,58
		M9	Management knowledge	0,01	0,57	0,07	0,36
		M10	Head Office location	0,00	0,70	0,22	0,08
		M11	Current workload	0,01	0,32	0,10	0,59
R	Reputation	R1	Experience Reputation	0,01	0,38	0,54	0,08
		R2	Relationship with client	0,02	0,05	0,35	0,60
		R3	Compliance to regulation	0,03	0,55	0,08	0,37
		R4	Failure track record	0,01	0,62	0,07	0,32
		R5	Company scale	0,01	0,32	0,06	0,62
		R6	Track record performance	0,03	0,36	0,09	0,56
S	Safety	S1	Safety management	0,01	0,57	0,07	0,36
		S2	Accident record	0,01	0,35	0,06	0,59
		S3	Ohsas procedure	0,02	0,54	0,07	0,39
		S4	Safety expert	0,02	0,55	0,07	0,38
		S5	Safety plan	0,02	0,61	0,07	0,32

TOTAL	**1,00**	**19,34**	**5,97**	**15,70**
Total Aggregate against weight		**0,48**	**0,23**	**0,28**

Source: Data of Research

Discussion

Based on the results of AHP's analysis of the opinions of 14 experts, it shows that the proposed contractor selection criteria formulation has a priority weight of the first bidding criteria with a weight of 35%, technical ability 22%, financial 13%, reputation 11%, management ability 10% and lastly K3 management with 9% figure. The results of the consistency test of the importance level assessment of all the criteria carried out by 14 experts who are contractors registered as partners at PT.TSI with assessment results above the average, show that the level of consistency ratio (CR) is below 10%, indicating that the assessment of each expert is still consistent and acceptable. Multi-Criteria analysis with Fuzzy AHP in the contractor selection process was carried out on prospective contractors who had passed to the top 3 in the tender package for the Structure, Architect and Plumbing work for the Restaurant construction project. Conducted by the Tender Committee consisting of 5 employees and contractor representatives. Using multi-criteria with known priority weights, resulting in contractor priority K1 with a value of 0.48, then K03 with a value of 0.28 and finally K02 with a value of 0.23

CONCLUSION AND RECOMMENDATION

Based on data processing using AHP against the MultiCriteria formulation of contractor selection based on a summary of previous research, followed by a Focus Group Discussion (FGD) then a multi-criteria analysis was carried out involving 14 experts who are contractors registered at PT.TSI with above average assessment results. Demonstrate the right criteria in the selection of the following contractors: Bid (P); Financial (F); Technical Ability (T); Management Ability (M); Reputation (R); and Safety management (S). Multi-Criteria analysis using the Fuzzy AHP method was carried out on 3 contractors who were included in the contractor designation process for the Rainforest Restaurant Development project in PT.TSI, showing the results of the assessment that the contractor declared the winner was K01. It can be concluded that the multi-criteria used can filter to get the best contractor. Based on the results of this study, it can be used as a recommendation for TSI management that in every contractor selection process it must be carried out in an objective way, using methods that can minimize bias or uncertainty factors. The use of multi-criteria with fuzzy-AHP analysis is one of the alternative methods used for optimization in contractor selection.

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