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Application of Fuzzy AHP Multi Criteria Decision to Determine Factor of Indonesian Shipyard's Subcontractor Selection

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Abstract:- The role of shipyards in Indonesia is very important to maintain the continuity and security of ships operating, especially in Indonesian and foreign waters. Several aspects that need to be considered in the ship repair work process, one of which is the selection of subcontractors who are appropriate, qualified and in accordance with project needs and regulations. This is very crucial to ensure that the ship can operate well after the repair process. The role of subcontractors in shipyard projects is very important to support project success. In this research, 9 criteria have been determined that influence the selection of subcontractors in the shipyard business sector in Indonesia. The 9 criteria are Cost, Quality, Safety, Insurance repair and warranty, Delivery Time, Experiences of Company, Past Performance, Cooperation Ability, Resources. The results in this research were calculated using the Fuzzy AHP method and obtained the weight of the most influential criteria in selecting the most appropriate subcontractor for the shipbuilding business sector. So it is hoped that in the future the shipyard can optimize project performance with the right selected subcontractors.

Keywords:- *Subcontractor Selection; Shipyard; Fuzzy AHP.*

I. INTRODUCTION

Failure of a project in the shipbuilding business can occur due to errors in decision making[1]. So this can cause a decrease in customers' confidence in the project they are working on. If this distrust from customers continues, it will affect the company's finances and profits due to a decrease in the target number of customers[2] (Prata ma Putra et al., n.d.)

In order not to make a mistake in choosing partners, it is very important for decision makers in a project to determine the selection of subcontractors. Subcontractors who are selected correctly will influence the success of a project so that they can minimize risks in the work, create a conducive atmosphere in the project, and minimize costs arising from the project [3]. The selection of subcontractors must be considered carefully by considering several aspects. Selection of subcontractors by only considering one indicator, for example price, cannot necessarily provide a guarantee that the competence of the workforce can fulfill project targets in accordance with the responsibilities given[4]. Some risks that can occur include subcontractors running out of funds and running away from responsibility for completing the work, and ultimately resulting in project delays. [5]

During the subcontractor selection process, decision makers must be careful. Decision making errors can result in disruption of project continuity, which can have a further impact on project completion time and increase project costs. Subcontractors are selected through an assessment stage based on multiple criteria containing qualitative and quantitative factors. Therefore, a method is needed that can combine these factors into a measurement[6]. The Multi Criteria Decision Making (MCDM) method is a decision making method used to determine the best alternative from a number of alternatives based on certain criteria. One method of Multi-Criteria Decision Making (MCDM) that is widely used is the Analytic Hierarchy Process (AHP). Fuzzy Logic is a tool that can be used to develop artificial intelligence (AI) systems. The digital values captured by fuzzy logic are the result of artificial reasoning of human cognition. This Fuzzy Logic theory has been developed by prof. Lofti Zadeh in 1965, and developed by researchers over several decades. [7]. Fuzzy logic solves many problems dealing with uncertain and uncertain data. Fuzzy Logic has several advantages in contexts that are uncertain, imprecise and still vague when compared to AHP or other MCDM methods. So Fuzzy Logic is more similar to human judgment. [8]

Combining the 2 methods between AHP and Fuzzy Logic is an approach that can overcome the limitations of AHP itself. Fuzzy -AHP can be used by decision makers to provide a preference evaluation at a more reasonable interval. Some of these intervals can produce a fuzzy scoring matrix, which can be adapted from the standard scoring of classical AHP. [8]

So it is hoped that the use of the Fuzzy AHP Method can be a solution for selecting subcontractors in the shipbuilding business sector in Indonesia.

II. EASE OF USE

A. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a concept initiated by Thomas L. Saaty in the 1970s. This method is a multi-criteria decision making model that designs a system capable of supporting human thinking which aims to optimize factors such as logic, experience, knowledge, emotions and intuition in an organized process. [9]

AHP is an approach created to prioritize different alternatives when multiple criteria need to be considered. This method allows decision makers to design complex problems as a hierarchy or series of interconnected levels. The essence of AHP is to solve complex and unstructured problems in their own groups, organize the groups hierarchically, and then replace human cognition with numerical values to produce relative comparisons. Through the aggregation process, the highest priority items can be identified.

Decision making in the AHP methodology is based on four main principles, namely:

- *Decomposition*

Once the problem is identified, the next step is decomposition, meaning breaking down the entire problem into its elements. If specific results are desired, solutions are also applied to those elements to achieve different levels of the problem. Therefore, this analysis process is called hierarchy. There are two types of hierarchies, namely complete and incomplete. We talk about a complete hierarchy if all elements are at the next level, otherwise the hierarchy formed is called an incomplete hierarchy.

- *Comparative*

In this principle, assessments are made based on the relative importance of two factors at a certain level to be compared with existing criteria. This kind of assessment is important, because it can influence the prioritization of several factors available to be used as a reference in decision making. From the evaluation results, it can be shown in a pairwise comparison matrix.

- *Synthesis of Priorities*

Then each pairwise comparison matrix looks for the eigenvectors of each pairwise comparison matrix to get local priorities. Since pairwise comparison matrices exist at each level, to achieve global prioritization, aggregation must be performed between local prioritization. This process is called priority setting. Overall prioritization is the weighting of sub-criteria and alternatives relative to the overall goal of the hierarchy/top level of the hierarchy. The way to get global priorities is to multiply the local priorities of sub-criteria and alternatives by the priority of higher criteria (parent criteria).

- *Logical Consistency*

Consistency has two meanings. First, similar objects can be grouped based on their uniformity and relevance. The second concerns the degree of relationship between objects according to certain criteria. If assessments are inconsistent, the process must be repeated to obtain a more accurate assessment.

B. Fuzzy AHP (F-AHP)

Fuzzy logic is logic that has fuzzy or fuzzy values between true and false. It was Professor Lotfi A. Zadeh, a professor at the University of California at Berkeley, who initiated and marketed the idea of a mechanism for handling or managing uncertainty called fuzzy logic. This method was first developed by an Iranian-American scientist, named Lotfi A. Zadeh through his writings in 1965 which contained fuzzy set theory.

Fuzzy logic has been developed in the United States, but its application is more general and widespread by Japanese practitioners by adapting it to the field of supervision and control. Fuzzy logic is used more in America than in Japan? An explanation: Western culture tends to view problems as black-white, yes-no, guilty-innocent, success-failure, or the equivalent of Aristotle's world of binary logic, while Eastern culture is more able to accept a "gray" approach. ” or “grey”. a more obscure world. . Fuzzy logic allows for member values between 0 and 1, levels of gray such as black and white, and in linguistic form, uncertain concepts such as “a little”, “only”, and “very”.

Fuzzy logic can be used in the fields of control theory, decision theory, and in the field of scientific management. The advantage of fuzzy logic is that it has the ability to reason in terms of language, so that in its design there is no need for mathematical equations for the objects being controlled. An example of the application of fuzzy logic in everyday life is that in 1990 the first fuzzy logic washing machine was produced in Japan (Matsushita Electric Industry Company). A fuzzy system is used to automatically determine the correct cycle based on the type and amount of dirt and the number of washes required. The inputs used are: level of dirt, type of stain and number of washes. This machine uses an optical sensor that emits light into the water and measures how the light travels to the other end. The dirtier it is, the dimmer the light.

C. Subkontractor Selection in Shipyard

Subcontractor workers or what are usually called work partners, are work units outside the organizational structure of company employees who are selected to carry out work activities according to orders from the company, in this case the shipyard. Subcontractors carry out various jobs in shipyards, starting from replating, repiping, machining, painting ships, cleaning maintenance and so on [10]

Labor productivity is a combination of performance, effectiveness and efficiency of the planning process. The work plan made by the factory must be optimized by utilizing the right workforce in the production process. Moreover, in the shipbuilding sector, the work load depends on the number

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of existing projects. Meanwhile, the number of projects at the shipyard is quite dynamic according to orders from ship owners. When project work is high, the company requires a lot of power, but if the project is low, the power needed does not need to be too much. To overcome this, shipbuilding companies work around this by using subcontractor workers. [10]

These subcontractors are given work according to the work load contained in ship construction and repair projects. In a state-owned shipbuilding company, these subcontractors are divided into 2 groups [10]. Namely:

- *Registered subcontractors*

All subcontractors who have registered with the company's work partners, but have not yet received a job or assignment from the company.

- *Selected subcontractors*

Selected subcontractors are registered subcontractors who have been appointed to carry out work activities in projects at shipbuilding companies.

Of these two categories, several shipbuilding companies do not even patent their criteria for determining selected subcontractors. Subcontractor assessments are decided according to individual preferences. For this reason, there is a need for measuring tools that can help decision makers in determining the selection of subcontractors in Indonesia in the shipbuilding business sector

III. RESEARCH METHODOLOGY

A. Conceptual Model

Fig. 1 is an image of a chart of the relationship between criteria in making decisions on selecting subcontractors. The chart explains that each criterion will be compared and become the basis for evaluating each alternative subcontractor.

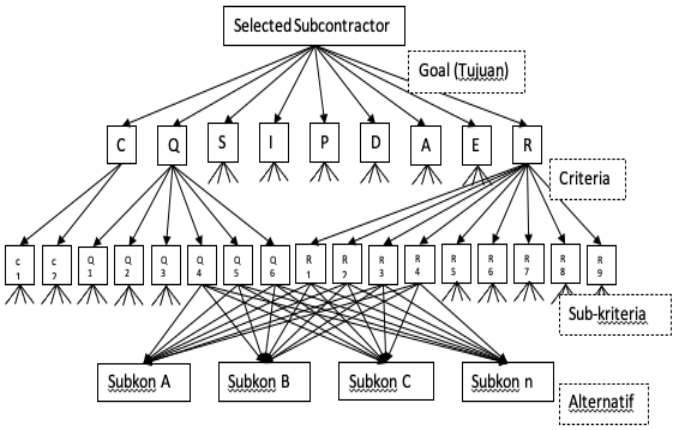

Fig. 1 Conceptual Model of Criterion Relationships

B. Number of Respondence and Data Collection

In accordance with the research objective of measuring the criteria in selecting subcontractors, the population or research object is the Decision Maker (expert) at shipyards in Indonesia. Experts were chosen as the population for the object of this research because they are the first party to directly assess the service quality of subcontractor services. The criteria of the respondence are :

- Experts are shipyard employees in Indonesia
- Expert as supervisor or manager of shipyard project work
- Expert as decision maker for selecting subcontractors in the shipyard

This research uses all dimensions of previous research, this is to produce precise information as far as these dimensions are relevant in measuring service quality in the shipbuilding industry sector. The indicators show in Fig. 2.

Of the 9 variables that have been arranged in table Fig.2 , the following are the criteria for assessing each variable based on a summary of several previous studies which will be explained in Table Fig. 3 below.

No	Indicators	Code	Operational Definition	References
1	Cost	C	The amount of the service price includes the subcontractor's payment method	[11]–[13]
2	Quality	Q	Subcontractor's commitment to quality standards of work results	[11]–[14]
3	Safety	S	Subcontractor's commitment to safety and security at work	[12], [14]
4	Insurance, repair and warranty	I	Subcontractor's commitment to repairs for after sales service and work guarantee	[11], [12], [14]
5	Delivery time	D	Subcontractor commitment in terms of completion of work tasks	[11]–[14]
6	Experiences of the company	E	*Subcontractor track record and experience on previous work projects*	[12], [14], [15]
7	Past Performance	P	Assessment of subcontractor performance in previous contracts	[14], [15]
8	Cooperation ability	A	Subcontractor's ability to coordinate and work together	[15], [16]
9	Resources	R	The ability of subcontractor labor resources to meet work standards	[15], [16]

Fig. 2 Main Indicators Table

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Code	Sub Criteria	Reference
	Cost	
C2	Payment terms	[11]–[13]
	Quality	
Q1	Comply with workmanship standards and subcontractor commitment to quality standards	[11]–[14]
Q2	Lack of rework on previous projects.	
	Safety	
S1	Subcontractor's commitment to inspection and maintenance of work equipment	[12], [14]
S2	Use of personal protective equipment, such as helmets, gloves, shoes, safety belts, etc.	
S3	Comply with workshop safety and protection regulations and guidelines	
	Insurance, repair and warranty	
I1	Quality assurance	[11], [12], [14]
I2	Subcon commitment to rework work	
I3	Warranty	
	Delivery Time	
D1	Timely completion of the work	[11]–[14]
	Experiences of the company	
E1	Subcon Reputation	[12], [14], [15]
E2	Number of similar projects that the subcon has previously completed	
	Past Performance	
P1	Previous assessment of subcontractor depends on last contract	[14], [15]
	Cooperation ability	
A1	Regular and effective communication with Shipyard	[15], [16]
A2	Willingness to discuss with shipyard before operations	
A3	Collaboration with project beneficiaries	
	Resources	
R1	Number of qualified craftsmen and labors	[15], [16]
R2	Efficiency	
R3	Ability to work at high altitudes	

Fig. 3 Sub-Criteria Table

Data collection was carried out primarily using a questionnaire system distributed to samples (experts) at several shipyards in Indonesia by distributing them via email. The questionnaire contains questions regarding indicators which are then used as a reference for measuring criteria in selecting subcontractors in shipyards in Indonesia. The criteria are calculated using the scale as follows in the table Fig. 4 bellow.

[9] Scale	Definition of Fuzzy Triangular Scale	Numbers
1	Equally Important	1,1,1
3	Weakly Important	2,3,4
5	Fairly Important	4,5,6
7	Strongly Important	6,7,8
9	Absolutely Important	9,9,9

Fig. 4 Saaty Scale Table

From the results of the questionnaire distributed to each expert at several shipyards in Indonesia, it was found that 100% of respondents agreed with the 9 main criteria in this research.

C. Eigen Value (Weight) and Consistency Ratio

The consistency ratio (CR) value is determined by calculating the eigenvalue, which is obtained by calculating the eigen factors (weights). Questionnaire findings are inconsistent and require correction if the CR value is more than 0.1. Questionnaire responses are reliable and consistent if the CR value is less than or equal to 0.1.The results of the eigenvalue calculation are as follows in Fig.5 :

Criteria	Eigen Value
Cost	0.65
Quality	1.82
Safety	2.73
Insurance and Warranty	1.25
Delivery Time	1.98
Experiences	0.31
Past Performance	0.30
Cooperation Ability	0.58
Resources	0.78

Fig. 5 Eigen Value of Main Criteria Table

Next, to ensure that the eigen value is reliable, it is necessary to calculate the consistency ratio as follows:

$$\lambda_{max} = \frac{\Sigma\left(\frac{EV}{W}\right)}{n}$$

$$\lambda_{max} = \frac{\left(\frac{0.65}{0.06}+\frac{1.82}{0.18}+\frac{2.73}{0.26}+\frac{1.25}{0.12}+\frac{1.98}{0.18}+\frac{0.31}{0.03}+\frac{0.30}{0.03}+\frac{0.58}{0.06}+\frac{0.78}{0.08}\right)}{9} = 10.129$$

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

$$CI = \frac{10.129 - 9}{9-1} = 0.14$$

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

$$CR = \frac{0.09}{1.45} = 0.09$$

Based on the calculation results, the consistency index (CI) value is 0.14. With a relative index (RI) value of 1.45, a consistency ratio value of 0.09 was found, where this value ≤ 0.1 means the results of this questionnaire are consistent.

D. Deometric Mean and Normalized of FAHP

Geometric Mean (GM) in the context of Fuzzy Analytical Hierarchy Process (FAHP) refers to the method of calculating the middle value or geometric average of a number of values related to pairwise comparisons in a decision hierarchy. In FAHP, pairwise comparison values are often expressed in terms of a fuzzy scale, which can be a fuzzy triangular number (TFN) or another form of fuzzy value. The use of the geometric mean in FAHP provides a weight or middle value that reflects the consistency between elements in the fuzzy decision hierarchy Fig.6.

Criteria	Geometric Mean		
Cost	0.64	0.84	1.07
Quality	1.59	2.08	2.52
Safety	4.14	4.21	4.27
Insurance and Warranty	0.82	0.99	1.20
Delivery Time	3.16	3.53	3.87
Experiences	0.23	0.27	0.35
Past Performance	0.26	0.31	0.39
Cooperation Ability	0.42	0.52	0.67
Resources	0.70	0.88	1.08
Total	11.96	13.63	15.42
Inverses	0.08	0.07	0.06
Increasing Order	0.06	0.07	0.08

Fig. 6 Geometric Mean of Main Criteria

Normalization in the Fuzzy Analytical Hierarchy Process (FAHP) is a process that aims to adjust or change the values in the pairwise comparison matrix so that they meet certain criteria and can be processed consistently Fig.7. This step is taken to overcome varying value scales between criteria or alternatives. Normalization can involve dividing each matrix element by its column or row total, depending on the normalization method used. The goal of normalization in FAHP is to ensure that the values used in subsequent calculations reflect accurate and consistent relative comparisons, thereby supporting more reliable decision making in multi-criteria contexts.

Criteria	Fuzzy Weight			Mi	Normalized
Cost	0.0416	0.0614	0.0892	0.0641	0.0627
Quality	0.1029	0.1527	0.2108	0.1555	0.1522
Safety	0.2682	0.3088	0.3572	0.3114	0.3048
Insurance and Warranty	0.0531	0.0728	0.1007	0.0756	0.0739
Delivery Time	0.2047	0.2587	0.3240	0.2625	0.2569
Experiences	0.0146	0.0199	0.0290	0.0212	0.0207
Past Performance	0.0171	0.0231	0.0323	0.0242	0.0236
Cooperation Ability	0.0274	0.0384	0.0562	0.0407	0.0398
Resources	0.0456	0.0643	0.0903	0.0667	0.0653
Total				1.0217	1.0000

Fig. 7 Fuzzy Weight Normalized

IV. RESULT AND DISCUSSION

This research, entitled "Fuzzy AHP Multi Criteria Decision Application to Determine Factors for Selection of Shipyard Subcontractors in Indonesia," provides in-depth insight into the priority criteria in selecting shipyard subcontractors. Evaluation of key criteria, such as cost, quality, safety, insurance, completion time, experience, previous performance, collaboration ability, and resources, using the AHP method showed that completion time ranked highest, followed by quality and safety. These findings reflect the urgency of returning vessels to operational service, providing valuable guidance for selecting the right partner in the Indonesian shipbuilding industry.

The application of AHP in selecting subcontractors can optimize the ship construction and maintenance process, reduce the risk of delays, and improve the quality of work results. In addition, the Fuzzy AHP approach, as discussed in this research, shows a change in the order of priorities between completion time, quality, and cost. The advantage of Fuzzy AHP in dealing with uncertainty, by considering variability in sub-criteria such as the level of compliance with Safety regulations, has a significant impact on decision making. This model is a first step towards developing a more robust and inclusive approach, especially with the integration of sustainability criteria.

The time for completing project work in a shipbuilding business sector is very important. Accuracy and speed of project completion time is the key to project success in a shipbuilding company. This has a big influence on the trust of ship owners and the smooth running of the company's cash flow. The role of subcontractors is very important in supporting project success. In accordance with the criteria that have been examined in this research, it provides a new perspective in considering the selection of subcontractors for Shipyards in Indonesia, by considering the weight of the criteria as follows in Fig.

From the results listed in Fig. 8 above, the total weighting value is used as a multiplying factor for each value of the criteria that influences the assessment of candidate subcontractors. So if formulated in the equation it is as follows:

Score of Subcontractor = (D1x0,22) + (Q1x0,16) + (Q2x0,04) + (C1x0,12) + …. + (E2x0,023)

Implementation of the results of this research in the shipbuilding industry in Indonesia has the potential to increase efficiency, timeliness and overall project quality. Further collaboration with industry can optimize this model according to practical needs and constraints. Thus, utilizing Fuzzy AHP, provides new insights in improving the robustness and applicability of models in subcontractor selection, offering a sustainable contribution to the development of best practices in the shipbuilding industry.

V. CONCLUSION

Evaluation using the AHP method highlights the urgency of completion time, quality and work safety as the main aspects. The application of AHP can provide practical benefits in optimizing ship construction and maintenance processes. Furthermore, the Fuzzy AHP approach changes the order of priorities, showing superiority in dealing with uncertainty.

This model is a first step towards the development of a more inclusive approach, with the potential to integrate sustainability criteria. Implementation of the results of this research has the potential to increase the efficiency and quality of shipbuilding projects in Indonesia, while collaboration with industry can optimize models according to practical needs. Thus, this research, with the Fuzzy AHP approach, makes a sustainable contribution to the development of best practices in the selection of subcontractors in the shipbuilding industry.

Pay attention to the urgency of completion time (Delivery Time). Since completion time ranks highest in subcontractor selection, companies should place special emphasis on subcontractor availability to meet tight deadlines.

Collaboration with parties who can guarantee good completion times can be a key factor in project success.

Focus on Safety and Quality. Although completion time is a priority, safety and quality also play a crucial role in the selection of subcontractors. Ensuring subcontractors are committed to safety standards and regulatory compliance can minimize the risk of accidents and increase confidence in work results.

Rank	Criteria	Mean Criteria	Sub Criteria	Mean Sub Criteria	Total
1	Delivery	0,2202	D1	1	0,2202
2	Quality	0,2107	Q1	0,79	0,166453
		0,2107	Q2	0,22	0,046354
3	Cost	0,1722	C1	0,72	0,123984
		0,1722	C2	0,31	0,053382
4	Safety	0,1508	S1	0,23	0,034684
		0,1508	S2	0,3	0,04524
		0,1508	S3	0,49	0,073892
5	Insurance, Repair, & Warranty	0,0982	I1	0,59	0,057938
		0,0982	I2	0,15	0,01473
		0,0982	I3	0,3	0,02946
6	Resources	0,0717	R1	0,55	0,039435
		0,0717	R2	0,28	0,020076
		0,0717	R3	0,22	0,015774
7	Cooperation Ability	0,0586	CA1	0,59	0,034574
		0,0586	CA2	0,44	0,025784
8	Past Performance	0,0462	P1	1	0,0462
9	Experiences of The Company	0,04	E1	0,44	0,0176
		0,04	E2	0,58	0,0232

Fig. 8 Result of Score and Rank of All Criteria

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