The selection of suitable fishing gear for fishermen in Madura Island using Fuzzy AHP and Fuzzy TOPSIS

by Hozairi Hozairi

The selection of suitable fishing gear for fishermen in Madura Island using Fuzzy AHP and Fuzzy TOPSIS

[1]Heru Lumaksono, [2]Hozairi

[1] Department of Ship Building Engineering, Shipbuilding Institute of Polytechnic Surabaya, Surabaya, Indonesia; [2] Department of Informatics Engineering, Islamic University of Madura, Pamekasan, Indonesia. Corresponding author: Hozairi, hozairi@gmail.com

Abstract. Madura Island, whose majority of the people work as fishermen, has the potential to increase their productivity by recommending suitable fishing gear for their area. This research will give recommendation of suitable decision to choose fishing gear which have good selectivity and good productive, the method developed in this research is combination of Fuzzy AHP and Fuzzy TOPSIS method. Fuzzy AHP is used to determine the weight of predefined criteria and Fuzzy TOPSIS is used to rank alternative decisions. The results of the weighting criteria are: selectivity = 0.213, productivity = 0.190, environmental impact = 0.182, quality of catch = 0.147, not dangerous = 0.138 and cost = 0.129. The calculation results using Fuzzy TOPSIS obtained the priority of fishing gear suitable for fishermen in Madura Island as follows: fishing = 0.682, ground fish pots = 0.589, gill nets = 0.504, trawl= 0.411, lift net = 0.327 and purse seine = 0.318. The results of the implementation of Fuzzy AHP and Fuzzy TOPSIS methods will be taken into consideration for decision makers to assist fishermen and local government to develop a kind of fishing gear that suits the needs of the community, environmentally friendly and does not violate the law.
Key Words: fishing gear, Fuzzy AHP, Fuzzy TOPSIS.

Introduction. To realize a sustainable capture fishery in accordance with the provisions of responsible fishery execution of the Code of conduct for Responsible Fisheries (CCRF), the exploitation of marine biological resources shall be carried out responsibly. Data from The State of the World Fisheries and Aquaculture states that 5% of the world's fisheries are in continuous production decline status, 16% have been over-exploited and exceeded the optimum production limits, 52% have been fully exploited, 23% of production can still be improved even in small amounts, 3% of fish resources are still below their optimum exploitation level and only 1% is in the recovery process through conservation programs (FAO 1995).

Based on these data, to maintain the sustainability of fish resources it is necessary to examine the use of environmentally friendly fishing gear in terms of operation of fishing gear, fishing area and so forth in accordance with the governance of responsible fisheries or the Code of Conduct for Responsible Fisheries (FAO 1995). In the future, the development trend of fishing technology is emphasized on environmentally friendly fishing technology in the hope of utilizing fishery resources in a sustainable manner. Eco-friendly fishing technology is a fishing tool that does not provide a negative impact on the environment, ie the extent to which the fishing tools do not damage the bottom of the water, no negative impact on biodiversity, resources and not resources (Damayanti 2005; Sumardi et al 2014; FAO 2016).

The majority of the people of Madura Island work as fishermen with various fishing gear. Based on data from the Central Bureau of Statistics of Pamekasan Regency in 2015, fishing gear that is widely used by fishermen in Madura Island are: fishing, Ground Fish Pots, Lift Net, Trawl, Gill nets and Purse Seine. Fisheries depend heavily on the availability of fish in unpredictable waters at all times. The use of fishing gear in the achievement of good production should really pay attention to the environmental balance by minimizing the negative impact on the life of aquatic biota. The purpose of this research is to determine the suitable fishing equipment for Fishermen in Madura Island, especially Pamekasan Regency in terms of technical, environmental, social and economic aspects (Regency 2017).

Determination of suitable fishing gear for Fishermen in Madura Island is a complex problem because the goal is to establish the best alternative from a number of alternatives based on several criteria. Therefore, to solve the problem can be solved by Multi Criteria Decision Making (MCDM) method, that is by combining Fuzzy Analytic

Hierarcy Process (Fuzzy AHP) and Fuzzy Technique for Order of Preference by Similarity to the Ideal Solution (Fuzzy TOPSIS) for produce the right decision (Gumus 2009; Önüt et al 2010; Kaya & Kahraman 2011; Awasthi & Chauhan 2012; Büyüközkan & Çifçi 2012; Kutlu & Ekmekçioğlu 2012; Lima Jr. et al 2014; Shukla et al 2014; Zyoud et al 2016; Hozairi & Krisnafi 2018).

Fuzzy AHP is one of the excellent MCDM methods to model the opinions of experts by doing pairwise comparisons of variables that become decisive in the decision making process (Hozairi & Ahmad 2015; Mafi-Gholami et al 2015). However, the Fuzzy AHP method is less effective to use with a large number of criteria and alternatives, to cover that weakness, it requires another method of decision making that is Fuzzy TOPSIS method, the method works using the principle that the chosen alternative must have the closest distance from the ideal positive solution and furthest from the ideal ideal solution by using the Euclidean distance to determine the relative proximity of an alternative with the optimal solution (Krisnafi et al 2017; Hozairi & Krisnafi 2018).

This study uses six criteria, namely: K1 = selectivity, K2 = productivity, K3 = environmental impacts, K4 = quality of catch, K5 = not dangerous, K6 = cost and six alternatives, namely: A1 = fishing, A2 = ground fish pots, A3 = lift net, trawl, A4 = gill nets and A6 = purse seine. The purpose of this study will be to select suitable fishing gear for fishermen in the island of Madura.

Material and Method. This research is located in Madura Island, the object of spreading the questionnaire is fisherman community in Pamekasan and Sampang Regency. The process of selecting gear that is environmentally friendly and has high productivity is a difficult problem, because every fishing gear has different level of importance. The method used to solve the problem is by combining Fuzzy AHP and Fuzzy TOPSIS method.

Figure 1 describes the stage of the most suitable fishing gear assessment process for Fishermen in Madura Island in terms of established criteria. The Fuzzy AHP method is used to assess the importance of each criterion, once the criterion rating rating is obtained, it will be used as a reference to the alternative rating by the Fuzzy TOPSIS method.

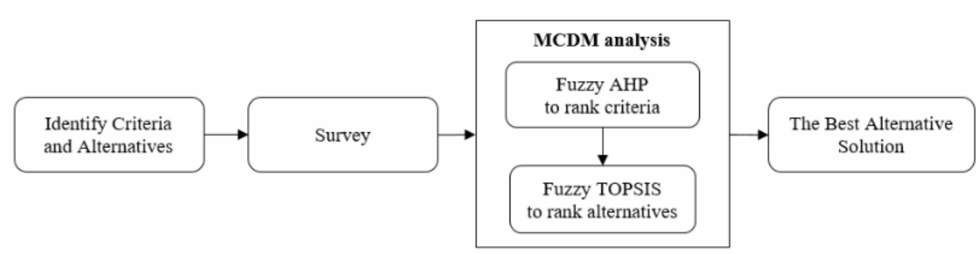


Figure 1. Block diagram of research stages.

Multi criteria decision making. Multi Criteria Decision Making (MCDM) is a decision-making method to establish the best alternative of a number of alternatives based on certain criteria. Criteria are usually the sizes, rules or standards used in decision making. Based on the purpose, MCDM can be divided into two models: Multi Atribute Decision Making (MADM) and Multi Objective Decision Making (MODM). Often MADM and MODM are used to solve multi-attribute and multi-objective problems (Pohekar & Ramachandran 2004).

There are several classifications of MCDM methods, namely: (1). by data type (deterministic, stochastic and fuzzy data types), (2). according to the decision maker (individual or group). The MCDM problem does not always provide a unique solution, the type difference may be to make a difference solution, that is:

1. Ideal solutions, criteria or attributes can be divided into two categories, namely: criteria whose value will be maximized or minimized.
2. A non-dominated solution, this solution is known as the optimal Pareto solution.
3. A satisfactory solution, is a subset of feasible solutions where each alternative goes beyond all the expected criteria.

4. A preferred solution, is the non-dominated solution that satisfies most decision makers.

Fuzzy Logic. Fuzzy logic is one of the components of Soft Computing. The basis of fuzzy logic is the fuzzy set theory. In the fuzzy set theory, the role of membership degree as a determinant of the existence of elements in a set is very important. The membership value or membership degree or membership function is the main characteristic of reasoning with fuzzy logic (Zadeh 1965).

Fuzzy logic is an enhancement of the application of boolean logic, to boolean algebra that recognizes notation 1 and 0. Fuzzy logic allows membership to be between 0 and 1. Therefore, a condition can be partially true and partly wrong at the same time. There are several reasons why people use fuzzy logic, that is:

1. The concept is easy to understand.
2. Very flexible.
3. Have tolerance to data that is not right.
4. Able to model very complex non-linear functions.
5. Be able to build and apply expert experiences directly without having to go through the training process.
6. Able to cooperate with conventional control techniques.
7. Fuzzy logic is based on natural language.

Fuzzy logic is an appropriate way to map an input space into an output space (Sri Kusumadewi, 2002). A fuzzy number represented on a Triangle Curve is basically a combination of two linear lines. The fuzzy number triangle curve has a membership function defined by three real numbers denoted as (l, m and u,) called Triangular Fuzzy Numbers (TFN) and commonly used because it has a simple calculation (Figure 2).

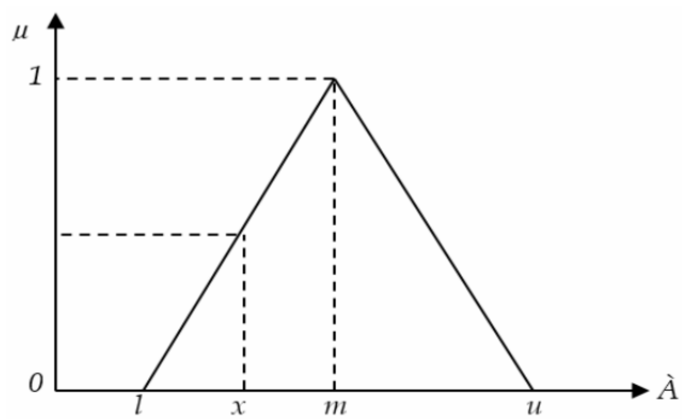


Figure 2. Illustration of fuzzy triangular number (TFN).

(l,m,u) can be defined as follows in equation.1

$$\mu\grave{A}_{(x)} = \begin{cases} 0, & x \leq l \\ \frac{x-l}{m-l} & l \leq x \leq m \\ \frac{x-u}{m-u} & m \leq x \leq u \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

Parameters (l, m, u) are real numbers, each of which shows the lowest possible value, the most favorable value, and the highest possible value (l <m <u), which illustrates the fuzzy case. Operational rules (algebraic operations) for two TFNs:

$\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{N} = (b_1, b_2, b_3)$ are:

(2)

$\tilde{A} \otimes \tilde{N} = (a_1, a_2, a_3) \otimes (b_1, b_2, b_3) = (a_1+b_1, a_2+b_2, a_3+b_3)$

$$\tilde{A} \otimes \tilde{N} = (a_1, a_2, a_3) \otimes (b_1, b_2, b_3) = (a_1b_1, a_2+b_2, a_3+b_3) \quad (3)$$

$$\tilde{A}^{-1} = (1/a_1, 1/a_2, 1/a_3) \quad (4)$$

Where ⊗ denotes extende summation of two TFNs, and ⊗ denotes the extended multiplication.

Fuzzy analytic hierarchy process (FAHP). Fuzzy Analytic Hierarchy Process (FAHP) is a combination of AHP method with fuzzy approach. FAHP covers the weaknesses of AHP, ie problems with criteria that have more subjective properties. Uncertainty of numbers is represented by a scale sequence.

The determination of FAHP membership degree developed by Chang (1996) uses Triangle Tringular Fuzzy Number (TFN) membership function. Triangle membership function is a combination of two lines (linear). The graph of the triangular membership function is illustrated in the form of a triangular curve as shown in Figure 2. Chang (1996) defines the value of the intensity of AHP into the triangular fuzzy scale that divides each fuzzy set by two (2), except for the intensity of the interest of one (1). The triangle fuzzy scale that Chang (1996) used can be seen in Table 1.

Table 1

TFN scale in variable linguistics

Linguistic scale for importance	*Fuzzy numbers*	*Triangular fuzzy number (TFN)*	*Reciprocal*
Just equal	1	(1, 1, 3)	(1/3, 1, 1)
Moderatly important	3	(1, 3, 5)	(1/5, 1/3, 1)
Strongly important	5	(3, 5, 7)	(1/7, 1/5, 1/3)
Very strong	7	(5, 7, 9)	(1/9, 1/7, 1/5)
Extremely strong	9	(7, 9, 9)	(1/9, 1/9, 1/7)

The stages of the Fuzzy Analytic Hierarchy Process (FAHP) method are similar to the AHP method. The following steps explain the procedure:

Step 1: Creating a hierarchical structure of problems to select fishing gear suitable for fishermen on the island of Madura as Figure 3. Before performing F-AHP calculations, the hierarchical structure of the problem is solved by using the AHP calculation to ensure consistency of the matrix value of the comparison. Input value of AHP comparison matrix is shown in Table 2.

The matrix comparison input value in Table 2 is processed to find the priority vector weight, lamda, CI, and CR. The value of matrix in Table 2 has been tested consistency index (CI) and consistency ratio (CR) the result shows consistent value (Saaty 2008), so the value of matrix comparison can be used as reference for fuzzy process.

The next step is to convert the AHP comparison matrix into Fuzzy AHP. The result of conversion of comparison matrix value can be seen in Table 3.

Table 2

Matrix comparison criteria with AHP

Criteria	*K1*	*K2*	*K3*	*K4*	*K5*	*K6*
K1	1.00	3.00	3.00	5.00	5.00	7.00
K2	0.33	1.00	1.00	5.00	5.00	7.00
K3	0.33	1.00	1.00	5.00	5.00	5.00
K4	0.20	0.20	0.20	1.00	3.00	3.00
K5	0.20	0.20	0.20	0.33	1.00	3.00
K6	0.14	0.14	0.20	0.33	0.33	1.00

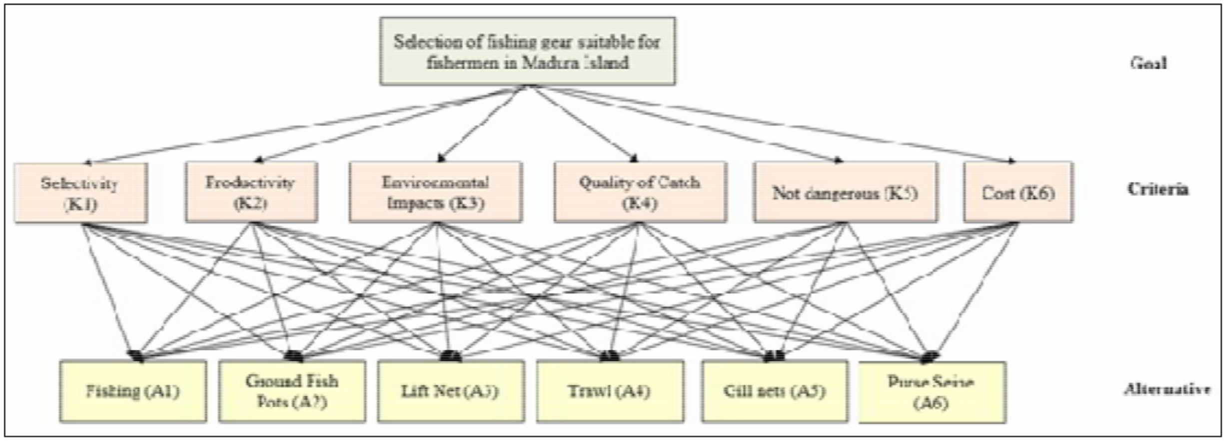


Figure 3. The hierarchical structure of fishing gear election suitable for fishermen on the island of Madura.

Table 3

Results of AHP decision matrix conversion to Fuzzy AHP

Criteria	K1			K2			K3			K4			K5			K6		
	L	*M*	*U*	*L*	*M*	*U*	*L*	*M*	*U*	*L*	*M*	*U*	*L*	*M*	*U*	*L*	*M*	*U*
K1	1.00	1.00	1.00	1.00	3.00	5.00	1.00	3.00	5.00	3.00	5.00	7.00	3.00	5.00	7.00	5.00	7.00	9.00
K2	1.00	0.33	0.20	1.00	1.00	1.00	1.00	1.00	1.00	3.00	5.00	7.00	3.00	5.00	7.00	5.00	7.00	9.00
K3	1.00	0.33	0.20	1.00	1.00	1.00	1.00	1.00	1.00	3.00	5.00	7.00	3.00	5.00	7.00	3.00	5.00	7.00
K4	0.33	0.20	0.14	0.33	0.20	0.14	0.33	0.20	0.14	1.00	1.00	1.00	1.00	3.00	5.00	1.00	3.00	5.00
K5	0.33	0.20	0.14	0.33	0.20	0.14	0.33	0.20	0.14	1.00	0.33	0.20	1.00	1.00	1.00	1.00	3.00	5.00
K6	0.20	0.14	0.11	0.20	0.14	0.11	0.11	0.20	0.14	1.00	0.33	0.20	1.00	0.33	0.20	1.00	1.00	1.00

Step 2: Determining the value of fuzzy synthesis (Si) priority by using the formula as follows:

$$S_i = \sum_{j=1}^{m} M_j^i \ x \ \frac{1}{\sum_{i=1}^{n}\sum_{i=1}^{m} M_i^j} \quad (5)$$

Where:

$$\sum_{j=1}^{m} M_j^i = \sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj \quad (6)$$

While:

$$\frac{1}{\sum_{j=1}^{n}\sum_{j=1}^{m} M_i^j} = \frac{1}{\sum_{i=1}^{n} ui, \sum_{i=1}^{n} mi, \sum_{i=1}^{n} li} \quad (7)$$

Step 3: Determining the Vector Value (V) and the Defuzification Value (d ').
If the results obtained in each fuzzy matrix, M2 ≥ M1 (M2 = (1, 2, m2, u2) and M1 = (l1, m1, u1) then the vector values can be formulated as follows:

$V (M_2 \geq M_1) = \sup [\min(\mu M_1(x), \min(\mu M_2(y)))]$

Or equal to the membership function of triangle as shown in Figure 2, so that the equation as follows:

$$V (M_2 \geq M_1) = \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_2 \geq \mu_1 \\ \dfrac{l_1 - \mu_2}{(m_2 - \mu_2) - (m_1 - l_1)} & otherwise \end{cases} \quad (8)$$

If the result of a fuzzy value is greater than k, Mi (i = 1,2, .. k) then the vector value can be defined as follows:

$V (M \geq M_1, M_2, ..., M_K) = V (M \geq M_1)$ and
$V (M \geq M_1)$
$V (M \geq M_k) = \min V (M \geq M_i)$ (9)

It is assumed that:

$d'(A_i) = \min V (S_i \geq S_k)$ (10)

For k = 1,2,...n; k ≠ I, then we get the value of vector weight as follows:

$W' = d'(A_i), d'(A_2), \ldots\ldots d'(A_n)^T$ (11)

Where $A_i = 1,2,\ldots\ldots,n$ is n decision element.

Step 4: Normalize the value of the fuzzy vector weight (W)
After normalization of equation (11) then the normalized vector weighting value as follows (12):

$W = d(A_i), d(A_2), \ldots\ldots d(A_n)^T$ (12)

Fuzzy TOPSIS. The *Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)* method is based on a well chosen alternative concept that not only has the shortest distance from a positive ideal solution ie maximizing benefit criteria and minimizing cost criteria (Yoon 1987), but also has the furthest distance from a negative ideal solution that maximizes cost criteria and minimizes benefit criteria.

TOPSIS is used in processing the data for each alternative in the database, which in the final result of the processing in the form of ranking based on predetermined criteria. TOPSIS is widely used because the concept is simple and easy to understand, computing is efficient and has the ability to measure the relative performance of decision alternatives in simple mathematical models.

The reason for the TOPSIS method combined with Fuzzy is to make it easier for decision makers to be more confident to provide qualitative judgments than to express judgments in the form of a single numerical value. Fuzzy TOPSIS is able to handle multi-criteria decision making by translating linguistic values into Fuzzy thus allowing decision makers to enter incomplete information. The algorithm of the Fuzzy TOPSIS method can be describe as follows:

Step 1: Selecting linguistic values x_{ij}, for alternatives regarding criteria. The fuzzy linguistic rating x_{ij}, makes the normal range of fuzzy triangle numbers [0, 1].

Step 2: *Create a normalized Decision Matrix*

Each element in the matrix D is normalized to obtain the normalized matrix **r.** Any normalization of **r** value can be done with the following calculation:

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} \qquad \text{For } i = 1,2,3,\ldots,m. \quad j = 1,2,3,\ldots,n. \qquad (13)$$

For *i = 1,2,3,…..,m.*
j = 1,2,3,…..,n.

Step 3: *Create a normalized weighting matrix*

Assigned weights W = (w_1, w_2, ..., w_n), so Weighted Normalized matrix V may be generated as follows:

$$V = \begin{bmatrix} W_{11}r_{11} & \ldots & W_{1n}r_{1n} \\ \ldots\ldots\ldots & \ldots & \ldots\ldots\ldots \\ W_{m1}r_{m1} & \ldots & W_{nm}r_{nm} \end{bmatrix} \qquad \text{For } i = 1,2,3,\ldots,m. \quad j = 1,2,3,\ldots,n. \qquad (14)$$

Step 4: *Determining Ideal Ideal Solutions and Negative IdealSolutions*

The positive solution is denoted by **A+** and the negative ideal solution is denoted by **A-**. Define the ideal solution (+) & (-).

$$A^+ = \{(\max v_{ij} | j \in J)(\min v_{ij} | j \in J), i = 1,2,3,\ldots,m\} = \{v_1^+, v_2^+, v_3^+\}$$
$$A^- = \{(\max v_{ij} | j \in J)(\min v_{ij} | j \in J), i = 1,2,3,\ldots,m\} = \{v_1^-, v_2^-, v_3^-\} \qquad (15)$$

Where:

V_{ij} = the matrix element V, row to-i and column to-j
J = {j=1,2,3,…, n and j due to benefit criteria)
J′ = {j=1,2,3,…, n and j due to cost criteria)

Step 5: *Calculating Separation Measure*

Separation measure is a measure of the distance from an alternative to a positive ideal solution and a negative ideal solution. The mathematical calculations are as follows:

- Separation measure for a positive ideal solution

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^+)^2} \qquad (16)$$

For *i=1,2,3,…,n*

- Separation measure for a negative ideal solution

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^-)^2} \qquad (17)$$

For *i=1,2,3,…,n*

Step 6: *Calculating Relative Proximity with Positive Ideal*

Relative proximity of alternatives **A+** with an ideal solution **A-** is represented by:

$$C_i = \frac{S_i^-}{S_i^- + S_i^+} \qquad (18)$$

With $0 < C_i$ and $i=1,2,3,\ldots,m$

Step 7: *Sorting results*
Alternatives can be ranked in the order of $\mathbf{C_i}$, therefore, the best alternative is one of the shortest distance to the ideal solution and furthest away with the ideal negative solution.

Results. This research begins by determining the criteria that become the consideration of the selection of suitable fishing gear for Madura Island Fisherman as Table 4. After the criteria is agreed, then decide the alternative (type of fishing gear) that will be in value.

Table 4

Criteria for selecting fishing gear

Code	*Criteria*
K1	Selectivity
K2	Productivity
K3	Environmental impacts
K4	Quality of catch
K5	Not dangerous
K6	Cost

Table 5 describes the type of fishing gear that is widely used by fishermen in Madura Island is 6 types, namely: fishing, ground fish pots, lift net, trawl, gill nets and purse seine. This research begins with the distribution of questionnaires to some respondents (fishermen, businessmen, government, academia and community leaders) who understand and understand the condition of fishermen and fishing gear used. The purpose of this questionnaire as input data to test the consistency of the assessment of each alternative, with rating ratings as follows:

1 = Very bad
2 = Bad
3 = Enough
4 = Good
5 = Very good

Table 5

Alternative to the selection of fishing gear

Code	*Criteria*
A1	Fishing
A2	Ground fish pots
A3	Lift net
A4	Trawl
A5	Gill nets
A6	Purse seine

Fuzzy AHP results*.* Fuzzy AHP is used to analyze the weight of interest between criteria by using the Saaty comparison scale. The purpose of this analysis is to obtain the weight of interest on each criterion. Stages of interest assessment process using Fuzzy AHP as follows:

Step 1: *Develop a hierarchical structure of criteria*

The determinants of the selection of suitable fishing gear for Fishermen in Madura Island are influenced by six criteria as shown in Figure 4.

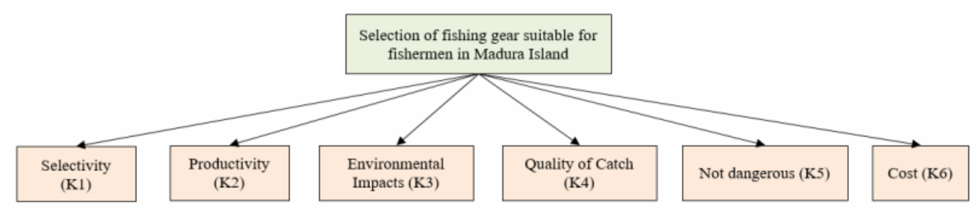


Figure 4. The hierarchical structure of fishing equipment selection criteria suitable for fishermen in Madura Island.

Step 2: *Calculate the value of fuzzy synthesis (S_i)*

The calculation of the AHP fuzzy systesis value leads to an estimate of the overall value of each criterion as in Table 6. Comparison matrix elements in Table 6 divided by the values on the number of rows. After that look for the eigen vector or the weight of each criterion by summing the values in each line, then divided by the number of criteria.

Table 6

Results of the calculation of the number of rows of each column and vice-versa

Criteria	*Number of rows*			*Number of columns*			*Inverse*		
	L	*M*	*U*	*L*	*M*	*U*	*L*	*M*	*U*
K1	14.00	24.00	34.00	51.73	75.35	102.22	0.01	0.01	0.02
K2	14.00	19.33	25.20						
K3	12.00	17.33	23.20						
K4	4.00	7.60	11.43						
K5	4.00	4.93	6.63						
K6	3.73	2.15	1.77						

After the value of the number of rows and columns is obtained, then use equations (5), (6) and (7). So we get the fuzzy synthesis value of each criterion (S_{Ki}) where i = 1,2 ... 4, as follows:

S_{Ki} = (Number of rows (L,M,U) * Inverse (L,M,U))
S_{K1} = ((14.00, 24.00, 34.00) * Inverse (0.01, 0.01, 0.02))
= (0.14, 0.32, 0.66)
S_{K2} = ((14.00, 19.33, 25.20) * Inverse (0.01, 0.01,0.02))
= (0.14, 0.26, 0.49)
S_{K3} = ((12.00, 17.33, 23.20) * Inverse (0.01, 0.01, 0.02))
= (0.12, 0.23, 0.45)
S_{K4} = ((4.00, 7.60, 11.43) * Inverse (0.01, 0.01, 0.02))
= (0.04, 0.10, 0.22)
S_{K5} = ((4.00, 4.93, 6.63) * Inverse (0.01, 0.01, 0.02))
= (0.04, 0.07, 0.13)
S_{K6} = ((3.73, 2.15, 1.77) * Inverse (0.01, 0.01, 0.02))
= (0.04, 0.03, 0.03)

The result of recapitulation of calculation of fuzzy synthesis value can be seen in Table 7.

Table 7

Result of fuzzy synthesis calculation (S_i)

Criteria	*Si*		
	L	*M*	*U*
K1	0.14	0.32	0.66
K2	0.14	0.26	0.49
K3	0.12	0.23	0.45
K4	0.04	0.10	0.22
K5	0.04	0.07	0.13
K6	0.04	0.03	0.03

Step 3: *The result of the vector value (V) and the ordinate value of defuzification*

This process uses a fuzzy approach that is the minimum implication (min) fuzzy function. After comparing the fuzzy synthesis value, we will get the de fi nificate ordinate value (d ') which is the minimum d value. Based on equations (8), (9), and (10), the values of vectors and deffuzification ordinate values of each criterion are as follows:

- Criterion 1 is Selectivity (K1), its vector value (V) is:

  (VK1) ≥ (VK2, VK3, VK4, VK5, VK6)

  Because the value of m1 ≥ m2 and u2 ≥ l1 is then used by the equations 9 and 10:

  VK1 ≥ VK2 = 1
  VK1 ≥ VK3 = 1
  VK1 ≥ VK4 = 1
  VK1 ≥ VK5 = 1
  VK1 ≥ VK6 = 1

  So the value (d') based on equation (11) is:

  d'(VK1) = min (1, 1, 1, 1, 1)
  d'(VK1) = 1

  In the same way as criterion 1 (selectivity), the value of vector for criteria 2, 3, 4, 5 and 6 ways used is same.

- Criterion 2 is Productivity (K2) obtained value as follows:

  VK2 ≥ VK1 = 1
  VK2 ≥ VK3 = 1
  VK2 ≥ VK4 = 1
  VK2 ≥ VK5 = 1
  VK2 ≥ VK6 = 1

  So obtained the value (d ') as follows:

  d'(VK2) = min (0.894, 1, 1, 1, 1)
  d'(VK2) = 0.894

- Criterion 3 is Environmental Impacts (K3) obtained value as follows:

  VK3 ≥ VK1 = 0.855
  VK3 ≥ VK2 = 0.930
  VK3 ≥ VK4 = 1
  VK3 ≥ VK5 = 1
  VK3 ≥ VK6 = 1

  So obtained the value (d') as follows:

  d'(VK3) = min (0.855, 0.930, 1, 1, 1)
  d'(VK3) = 0.855

- Criterion 4 is Quality of catch (K4) as follows:

  VK4 ≥ VK1 = 0.705
  VK4 ≥ VK2 = 0.692
  VK4 ≥ VK3 = 0.719
  VK4 ≥ VK5 = 1
  VK4 ≥ VK6 = 1

  So obtained the value (d') as follows:

  d'(VK4) = min (0.705, 0.692, 0.719, 1, 1)
  d'(VK4) = 0.692

- Criterion 5 is Not dangerous (K5) as follows:

  VK5 ≥ VK1 = 0.673
  VK5 ≥ VK2 = 0.647
  VK5 ≥ VK3 = 0.668
  VK5 ≥ VK4 = 0.837
  VK5 ≥ VK6 = 1

  So obtained the value (d') as follows:

  d'(VK5) = min (0.673, 0.647, 0.668, 0.837, 1)
  d'(VK5) = 0.647

- Criterion 6 is Cost (K6) as follows:

  VK6 ≥ VK1 = 0.642
  VK6 ≥ VK2 = 0.606
  VK6 ≥ VK3 = 0.622
  VK6 ≥ VK4 = 0.715
  VK6 ≥ VK5 = 0.707

So obtained the value (d') as follows:

d'(VK6) = min (0.642, 0.606, 0.622, 0.715, 0.707)

d'(VK6) = 0.606

Based on the ordinate values K1, K2, K3, K4, K5 and K6, then the value of the vector weight can be determined according to equation (11) as follows:

$W' = (1, 0.894, 0.855, 0.692, 0.647, 0.606)^T$

Step 4: *Normalize the value of the vector weight (W)*

Normalization is obtained from the value of the vector weight divided by the total value of the weight of the vector itself as in equation 12.

$W_{Total} = (1 + 0.894 + 0.855 + 0.692 + 0.647 + 0.606)$

$W_{Tot} = 3.693$

$W = (1/W_{tot}, 0.894/ W_{tot}, 0.855/ W_{tot}, 0.692/ W_{tot}, 0.647/ W_{tot}, 0.606/ W_{tot})$

$W = (0.271, 0.242, 0.231, 0.187, 0.175, 0.164)$

$W_{normalization} = 1.271$

The ranking for each criterion is obtained as follows:

K1 = 0.271/1.271 = 0.213
K2 = 0.242/1.271 = 0.190
K3 = 0.231/1.271 = 0.182
K4 = 0.187/1.271 = 0.147
K5 = 0.175/1.271 = 0.138
K6 = 0.164/1.271 = 0.129

The overall result of the process of normalizing the value of the vector weight (W) and the criteria rank can be seen in Table 8. The weight of interest generated with Fuzzy AHP will be considered or multiplied against the weighted normalization matrix in Fuzzy TOPSIS.

Table 8

Result of normalization of vector weight (W) and ranking criteria

C	V(K1 >= K2)	1			0			Otherwise	Summary of degree	Mean of degree	Weight vector	Rank
		M2>=M1			L1>=U2			(LI-U2)/(M2-U2)-(M1-L1)				
		M2	M1	deg	L1	U2	deg	degree				
K1	K1 >= K2	0.319	0.257	1					1	1	0.271	0.213
	K1 >= K3	0.319	0.230	1					1			
	K1 >= K4	0.319	0.101	1					1			
	K1 >= K5	0.319	0.065	1					1			
	K1 >= K6	0.319	0.029	1					1			
K2	K2 >= K1	0.257	0.319	Next	0.137	0.657	Next	0.894	0.894	0.894	0.242	0.190
	K2 >= K3	0.257	0.230	1					1			
	K2 >= K4	0.257	0.101	1					1			
	K2 >= K5	0.257	0.065	1					1			
	K2 >= K6	0.257	0.029	1					1			
K3	K3 >= K1	0.230	0.319	Next	0.137	0.657	Next	0.855	0.855	0.855	0.231	0.182
	K3 >= K2	0.230	0.257	Next	0.137	0.487	Next	0.930	0.930			
	K3 >= K4	0.230	0.101	1					1			
	K3 >= K5	0.230	0.065	1					1			
	K3 >= K6	0.230	0.029	1					1			
K4	K4 >= K1	0.101	0.319	Next	0.137	0.657	Next	0.705	0.705	0.692	0.187	0.147
	K4 >= K2	0.101	0.257	Next	0.137	0.487	Next	0.692	0.692			
	K4 >= K3	0.101	0.230	Next	0.117	0.448	Next	0.719	0.719			
	K4 >= K5	0.101	0.065	1					1			
	K4 >= K6	0.101	0.029	1					1			
K5	K5 >= K1	0.065	0.319	Next	0.137	0.657	Next	0.673	0.673	0.647	0.175	0.138
	K5 >= K2	0.065	0.257	Next	0.137	0.487	Next	0.647	0.647			
	K5 >= K3	0.065	0.230	Next	0.117	0.448	Next	0.668	0.668			
	K5 >= K4	0.065	0.101	Next	0.039	0.221	Next	0.837	0.837			
	K5 >= K6	0.065	0.029	1					1			
K6	K6 >= K1	0.029	0.319	Next	0.137	0.657	Next	0.642	0.642	0.606	0.164	0.129
	K6 >= K2	0.029	0.257	Next	0.137	0.487	Next	0.606	0.606			
	K6 >= K3	0.029	0.230	Next	0.117	0.448	Next	0.622	0.622			
	K6 >= K4	0.029	0.101	Next	0.039	0.221	Next	0.715	0.715			
	K6 >= K5	0.029	0.065	Next	0.039	0.128	Next	0.707	0.707			
									Total	3.693	1.271	1.000

Fuzzy TOPSIS results. The results of the distribution of 100 questionnaires to the respondents are: fishermen, community leaders, Government, academics, entrepreneurs who understand about environmentally friendly fishing gear in Madura Island will be analyzed using Fuzzy TOPSIS. The assessment scores in the questionnaire use a range of values between 1-5 as shown in Table 9.

Table 9

Rating of interest

Score	*Rating of interest*
1	Not at all important
2	Slightly important
3	Fairly important
4	Important
5	Very Important

The workings of Fuzzy TOPSIS use the principle that the chosen alternative must have the shortest distance from the ideal positive solution and furthest from the ideal negative solution by using the Euclidean distance. Fuzzy TOPSIS calculations use triangular fuzzy numbers on decision making such as Table 10.

Table 10

Convert rating of interest to Fuzzy number

Condition	*Fuzzy number*
Not at all important	(0, 0, 0.25)
Slightly important	(0, 0.25, 0.75)
Fairly important	(0.25, 0.5, 0.75)
Important	(0.5, 0.75, 1)
Very Important	(0.75, 1, 1)

The result of questionnaire assessment based on predetermined rating value can be seen in Table 11. Then the next step is to convert into fuzzy number according to the fuzzy set in Table 12.

Table 11

Result of recapitulation of rating value of questionnaire

Alternative	*K1*	*K2*	*K3*	*K4*	*K5*	*K6*
A1	5	3	4	4	4	4
A2	4	3	4	4	4	4
A3	3	4	3	4	4	3
A4	3	5	3	4	4	3
A5	3	3	4	4	4	4
A6	2	5	3	4	4	3

Table 12

Results of converting the questionnaire to Fuzzy number

Alter	K1			K2			K3			K4			K5			K6		
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
A1	0.75	1.00	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00
A2	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00
A3	0.25	0.50	0.75	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.25	0.50	0.75
A4	0.25	0.50	0.75	0.75	1.00	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.25	0.50	0.75
A5	0.25	0.50	0.75	0.75	1.00	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00
A6	0.00	0.25	0.75	0.75	1.00	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.25	0.50	0.75

Next to form a decision matrix of fuzzy number results, then the next step is the defuzification process that is every alternative in each criteria is taken the average value so that obtained the value of decision matrix as in Table 13.

Table 13

Result of normalization matrix of Fuzzy number

Alternative	*K1*	*K2*	*K3*	*K4*	*K5*	*K6*
A1	0.92	0.50	0.75	0.75	0.75	0.75
A2	0.75	0.50	0.75	0.75	0.75	0.75
A3	0.50	0.75	0.50	0.75	0.75	0.50
A4	0.50	0.92	0.50	0.75	0.75	0.50
A5	0.50	0.92	0.75	0.75	0.75	0.75
A6	0.33	0.92	0.50	0.75	0.75	0.50
Average	0.58	0.75	0.63	0.75	0.75	0.63

Having obtained the decision matrix in Table 13, the next step is to find the squared and root values in each criterion of the decision alternative as in equation (13). Squares and root calculation results are shown in Table 14.

Table 14

Value squares and roots

Criteria	*K1*	*K2*	*K3*	*K4*	*K5*	*K6*
Square	2.264	3.583	2.438	3.375	3.375	2.438
Root	1.505	1.893	1.561	1.837	1.837	1.561

Having obtained the value of squares and roots, then the next step is to normalize the matrix according to equation (14) is the multiplication of decision matrix with the root value in each criterion. Results of Fuzzy TOPSIS normalization matrix are shown in Table 15.

Table 15

Normalization matrix of TOPSIS fuzzy method

Alternative	*K1*	*K2*	*K3*	*K4*	*K5*	*K6*
A1	0.609	0.264	0.480	0.408	0.408	0.480
A2	0.498	0.264	0.480	0.408	0.408	0.480
A3	0.332	0.396	0.320	0.408	0.408	0.320
A4	0.332	0.484	0.320	0.408	0.408	0.320
A5	0.332	0.484	0.480	0.408	0.408	0.480
A6	0.222	0.484	0.320	0.408	0.408	0.320

The result of the decision matrix normalization Table 15 needs to be multiplied by the weighting of the criteria results that have been generated by Fuzzy AHP. The weight of the criteria resulting from the comparison between the interest as follows:

K1 = 0.213
K2 = 0.190
K3 = 0.182
K4 = 0.147
K5 = 0.138
K6 = 0.129

The multiplication result between the weight of Fuzzy AHP and the normalized decision matrix can be seen in Table 16.

Table 16

Normalized weighted matrix

Alternative	*K1*	*K2*	*K3*	*K4*	*K5*	*K6*
A1	0.130	0.050	0.087	0.060	0.056	0.062
A2	0.106	0.050	0.087	0.060	0.056	0.062
A3	0.071	0.075	0.058	0.060	0.056	0.041
A4	0.071	0.092	0.058	0.060	0.056	0.041
A5	0.071	0.092	0.087	0.060	0.056	0.062
A6	0.047	0.092	0.058	0.060	0.056	0.041

After obtaining a weighted normalization matrix in Table 16, it then looks for the maximum and minimum values for each criterion such as equation (15). The result of determining the maximum and minimum values in the weighted normalization matrix can be seen in Table 17.

Table 17

Results of the maximum and minimum values for each criterion

Value	*K1*	*K2*	*K3*	*K4*	*K5*	*K6*
Maximum	0.130	0.092	0.087	0.060	0.056	0.062
Minimum	0.047	0.050	0.058	0.060	0.056	0.041

Having obtained the maximum and minimum values on each of the criteria as shown in Table 17, the next step is to measure the proximity of an alternative to a positive ideal solution and a negative ideal solution. The calculation of the square and root values corresponds to equations (16) and (17). The calculation of the benefit value (A +) and the cost value (A-) can be seen in Tables 18 and 19.

Table 18

Value of squares on each alternative

Square value	*Benefit*	*Cost*
A1	0.002	0.008
A2	0.002	0.005
A3	0.005	0.001
A4	0.005	0.002
A5	0.003	0.004
A6	0.008	0.002

Table 19

Root values in each alternative

Root value	*Benefit*	*Cost*
A1	0.042	0.090
A2	0.048	0.069
A3	0.071	0.034
A4	0.069	0.048
A5	0.059	0.060
A6	0.090	0.042

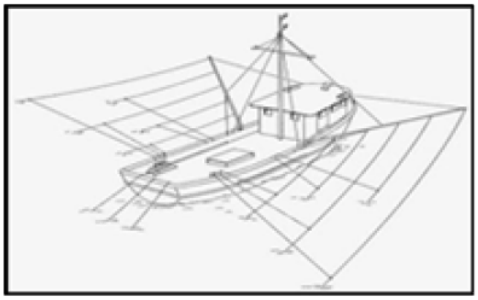
After obtaining the root value of each alternative, the value of benefit (A +) and cost value (A-) will be used as a reference to determine the priority recommended by Fuzzy TOPSIS. The mathematical equation for finding the priority value according to equation (18), the result of the priority value can be seen in Table 20.

Table 20

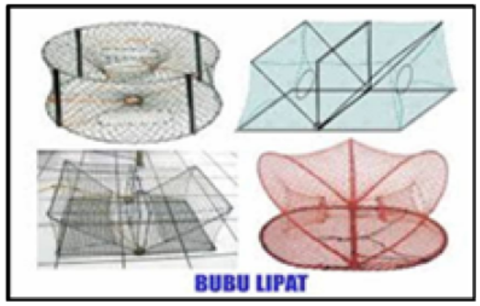
The priority value of each alternative

Alternative	*Priority value*	*Rank*
A1	0.682	1
A2	0.589	2
A3	0.327	5
A4	0.411	4
A5	0.504	3
A6	0.318	6

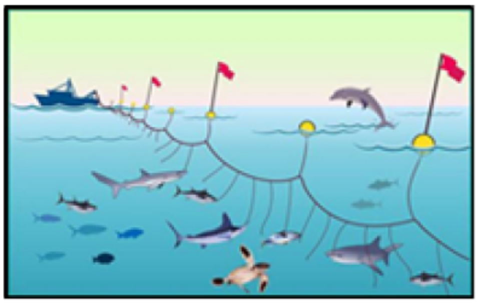
The result of the ranking of some fishing gear suitable for fisherman in Madura Island are shown in Figure 5.



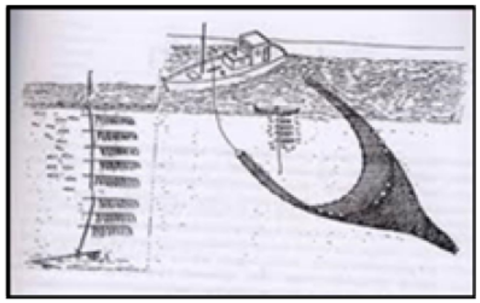
Fishing (A1 = 0.682)



Ground fish pots (A2 = 0.589)

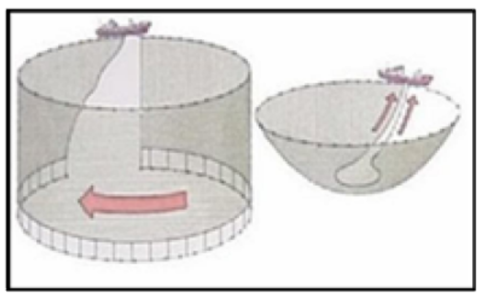


Gill nets (A5 = 0.504)



Trawl (A4 = 0.411)

Lift net (A3 = 0.327)



Purse seine (A6 = 0.318)

Figure 5. The priority weight that is suitable for fishing gear Fisherman in Madura Island.

The results of prioritized fishing equipment priority ranking for fishermen in Madura Island, especially Pamekasan and Sampang Regency are: [1] fishing = 0.682, [2] ground fish pots = 0.589. These two fishing gears are good in selectivity but low in productivity. Next [3] gill nets = 0.504, [4] trawl = 0.411, [5] lift net = 0.327. These three fishing gears are both in terms of selectivity and good as well as productivity. Furthermore [6] purse seine = 0.318 this tool from the side of high productivity but damaging the environment.

Figure 6 shows that the results of this study recommend 3 (three) things:

1. the fishing gear with high selectivity and low productivity;
2. the fishing gear with good selectivity and good productivity;
3. the fishing gear with low selectivity and high productivity.

Low selectivity fishing gear will produce fish that are not targeted for catch so that the fish will be discarded, with the high catches being disposed of it indicates that the fishing gear is not selective.

If the low selectivity will damage the environment and violate Indonesian Government and FAO regulations. So the recommendation of this research is to choose two types of fishing gear, namely:

1. the fishing gear with high selectivity and low productivity;
2. the fishing gear with good selectivity and good productivity.

Fishing gear with good selectivity are attempted only to catch fish that are the only catch target. There are two kinds of selectivity that are sub-criteria, namely the selectivity of the size and selectivity of the catch type and there are four sub criteria assessed, where the assessor is reviewed from the lowest to the highest:

1. more than three species of different size;
2. at most three species of different size;
3. less than three species of approximately the same size;
4. one species of the same size.

The development of a fishing gear in an area can be seen from the condition of the fishing gear, whether the fishing gear is socially acceptable, economic, public culture and applicable legislation. The criteria will be assessed as follows:

1. low cost investment;
2. profitable;
3. not contrary to culture;
4. not prohibited by law.

In general, the recommended fishing gear from the results of this study has considered the four criteria, so that the results of research fishing gear suitable for fishermen on the island of Madura, especially in Pamekasan and Sampang are as follows:

1. fishing;
2. ground fish pots;
3. lift net;
4. trawl;
5. gill nets.

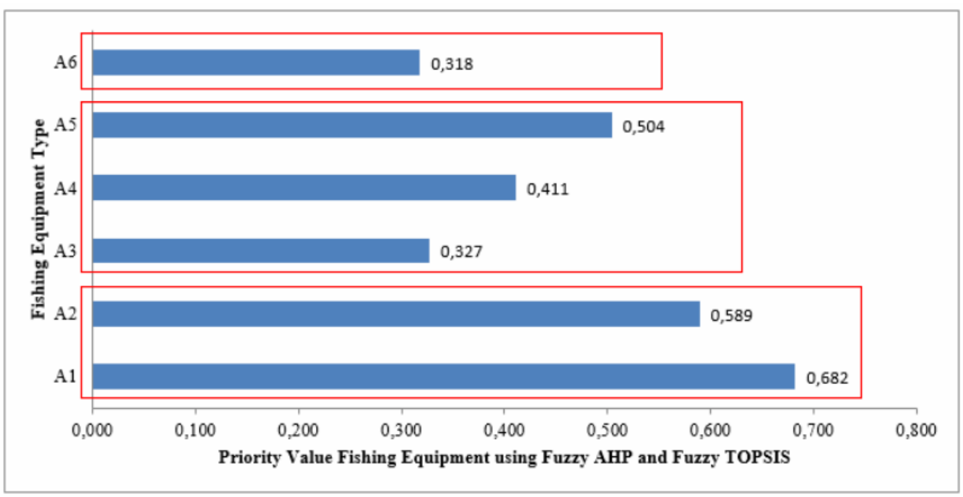


Figure 6. Priority value for each alternative.

Conclusions. The application of Fuzzy AHP and Fuzzy TOPSIS methods for the selection of suitable fishing gear for fishermen in Madura Island can help provide the best alternative recommendations for decision makers. The MCDM method with the combination of Fuzzy AHP and Fuzzy TOPSIS is sufficient to be used for the selection of suitable fishing gear for fishermen in Madura Island. Fuzzy AHP is used to determine the weight of predefined criteria and Fuzzy TOPSIS is used to rank alternative decisions. The results of the weighting criteria using the Fuzzy AHP method obtained by weighting the value as follows: selectivity = 0.213, productivity = 0.190, environmental impact = 0.182, quality of catch = 0.147, not dangerous = 0.138 and cost = 0.129. The calculation results using Fuzzy TOPSIS obtained the priority of fishing gear suitable for fishermen in Madura Island as follows: fishing = 0.682, ground fish pots = 0.589, gill nets = 0.504, trawl= 0.411, lift net = 0.327 and purse seine = 0.318. The results of the implementation of Fuzzy AHP and Fuzzy TOPSIS methods will be taken into consideration for decision makers to assist Fishermen and Local Government to develop a kind of fishing gear that suits the needs of the community, environmentally friendly and does not violate the law.

Acknowledgements. Thank you for the amount of the Ministry of Research, Technology, and Higher Education of Republic Of Indonesia, Shipbuilding Institute of Polytechnic Surabaya and Islamic University Of Madura has given permission joint research using internal funds Universities respectively.

References

Awasthi A., Chauhan S. S., 2012 A hybrid approach integrating affinity diagram , AHP and Fuzzy TOPSIS for sustainable city logistics planning. Applied Mathematical Modelling 36(2):573-84.

Büyüközkan G., Çifçi G., 2012 A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry. Expert Systems with Applications 39(3):2341-2354.

Chang D. Y., 1996 Applications of the extent analysis method on fuzzy AHP. European Journal of Operational Research 95(3):649-655.

Damayanti A. A., 2005 [Environmental friendly coral reef fishing unit using basic rawai in east Lombok Regency, West Nusa Tenggara]. Thesis, Institut Pertanian Bogor, 77 pp. [in Indonesian]

FAO, 1995 Code of conduct for responsible fisheries. FAO, Rome, 41 pp.

FAO, 2016 The state of world fisheries and aquaculture 2016: contributing to food security and nutrition for all. FAO, Rome, 200 pp.

Gumus A. T., 2009 Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. Expert Systems with Applications 36(2):4067-4074.

Hozairi, Ahmad, 2015 Selection of creative industry sector ICT suitable developed in Pesantren using fuzzy AHP. Journal of Theoretical and Applied Information Technology 53(1):131-136.

Hozairi, Krisnafi Y., 2018 Decision support system determination of main work unit in WPP-711 using fuzzy TOPSIS. Knowledge Engineering and Data Science 1(1):8-19.

Kaya T., Kahraman C., 2011 Multicriteria decision making in energy planning using a modified fuzzy TOPSIS methodology. Expert Systems with Applications 38(6): 6577-6585.

Krisnafi Y., Hozairi, Iskandar B. H., Wisudo S. H., Haluan J., 2017 [Decision support system for determining priorities of fisheries surveillance areas (WPP-711) using AHP-TOPSIS method]. Seminar Nasional Ilmu Terapan (SNITER) 2017 – Universitas Widya Kartika, pp. 1-8. [in Indonesian]

Kutlu A. C., Ekmekçioğlu M., 2012 Fuzzy failure modes and effects analysis by using fuzzy TOPSIS-based fuzzy AHP. Expert Systems with Applications 39(1):61-67.

Lima Jr. F. R., Osiro L., Ribeiro Carpinetti L. C., 2014 A comparison between fuzzy AHP and fuzzy TOPSIS methods to supplier selection. Applied Soft Computing 21:194-209.

Mafi-Gholami D., Feghhi J., Danehkar A., Yarali N., 2015 Prioritizing stresses and disturbances affecting mangrove forests using Fuzzy Analytic Hierarchy Process (FAHP). Case study: mangrove forests of Hormozgan Province, Iran. AES Bioflux 7(3):442-459.

Önüt S., Efendigil T., Kara S. S., 2010 A combined fuzzy MCDM approach for selecting shopping center site: an example from Istanbul, Turkey. Expert Systems with Applications 37(3):1973-1980.

Pohekar S. D., Ramachandran M., 2004 Application of multi-criteria decision making to sustainable energy planning - a review. Renewable and Sustainable Energy Reviews 8(4):365-381.

Regency, Central Statistics Agency of Pamekasan, 2017 Pamekasan Dalam Angka 2017. [in Indonesian]

Saaty T. L., 2008 Decision making with the analytic hierarchy process. International Journal of Services Sciences 1(1):83-98.

Shukla R. K., Garg D., Agarwal A., 2014 An integrated approach of fuzzy AHP and fuzzy TOPSIS in modeling supply chain coordination. Production and Manufacturing Research 2(1):415-437.

Sumardi Z., Sarong M. A., Nasir M., 2014 [Environmentally friendly fishing tools based on the Code of Conduct for Responsible Fisheries in Banda Aceh city]. Jurnal Agrisep 15(2):10-18. [in Indonesian]

Yoon K., 1987 A reconciliation among discrete compromise solutions. Journal of the Operational Research Society 38(3):272-286.

Zadeh L. A., 1965 Fuzzy sets. Information and Control 8(3):338-353.

Zyoud S., Kaufmann L. G., Shaheen H., Samhan S., Fuchs-Hanusch D., 2016 A framework for water loss management in developing countries under fuzzy environment: integration of fuzzy AHP with fuzzy TOPSIS. Expert Systems with Applications 61:86-105.

Received: 29 April 2018. Accepted: 28 May 2018. Published online: 30 June 2018.
Authors:
Heru Lumaksono, Department of Ship Building Engineering, Shipbuilding Institute of Polytechnic Surabaya, Surabaya, Indonesia, e-mail: heruppns@gmail.com
Hozairi, Department of Informatics Engineering, Islamic University of Madura, Pamekasan, Indonesia, e-mail: dr.hozairi@gmail.com

How to cite this article:
Lumaksono H., Hozairi, 2018 The selection of suitable fishing gear for fishermen in Madura Island using Fuzzy AHP and Fuzzy TOPSIS. Ecoterra 15(2):34-51.

The selection of suitable fishing gear for fishermen in Madura Island using Fuzzy AHP and Fuzzy TOPSIS

ORIGINALITY REPORT

10%	10%	0%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	journal2.um.ac.id Internet Source	10%

Exclude quotes	Off	Exclude matches	< 10%
Exclude bibliography	Off		