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Analysis of Fuzzy TOPSIS Method in Determining Priority of Small Dams Construction

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Abstract. The limited government budget for the construction of small dam in Semarang Regency has led to the need to determine the construction priorities. However, the large number of construction's technical aspects causes the determination of the construction priorities to be difficult. One of the best methods for multi-criteria decision making is the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS). However, ranking and weighting of the criteria that use in these constructions were difficult. It was caused by human assessment factors that were less precise especially on linguistic variables criteria. Therefore, a fuzzy logic was needed for calculating these criteria. There are eight alternatives of small dams and seven criteria of technical aspects analyzed in this study. The first step was determining membership function and weighting each criteria. Then, TOPSIS method was applied to ranked eight alternatives. The highest priority was determined by finding alternative that has the largest closeness coefficient (CCi). It represents alternative with closest distance to fuzzy positive ideal solution and farthest distance to fuzzy negative ideal solution. Based on analysis, Mluweh Dams has the highest CCi value of 0.612. It could be concluded that Mluweh Dams is the highest construction priority of small dams in Semarang Regency.

Keywords: fuzzy logic, TOPSIS, construction priority, small dams

INTRODUCTION

One of the problems of water resources management in Indonesia is that water resource potential is still fluctuating. During the rainy season, the water resource potential is excessive so that it causes flooding. Meanwhile, during dry season, many regions are still experiencing drought. These conditions led to the need for good management and development of water resources so that it can support people's lives.

One of water resources infrastructures that have the potential to solve these problems is a small dam. Currently, a small dam is also one of the government's development priorities. Therefore, the government plans to build many small dams. However, one of the problems that occur in Indonesia is the limited government budgets in infrastructure development. This condition has led to the need for determining the small dams' construction priority.

However, determining the priority of small dams' construction is difficult to perform because of the many technical aspects of small dams' construction. Therefore, a multi-criteria decision making method is necessary in determining the priority of this small dams' construction. One of the methods used for multi-criteria decision making is the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) [1]. TOPSIS method is a method that was first introduced by Hwang and Yoon [2]. This method requires ranking and weighting criteria. These are important to determine the best ideal solution. However, ranking and weighting the criteria that use in this construction were difficult because of several aspects (linguistic variables) that require human assessment. Human assessment of each criterion that is unclear and different causes determining the appropriate numeric value for these criteria was difficult to do. Therefore in this study, fuzzy logic was required to calculate these linguistic variable criteria [3].

Fuzzy TOPSIS method is the appropriate method to determine construction priority. There are many literature examples of implementation of Fuzzy TOPSIS method for determining construction priority. Fuzzy

TOPSIS method for selecting spillway of a dam has five alternative spillway types and nine criteria [4]. Other studies conducted by Ouma et al used Fuzzy TOPSIS method for determining road pavement maintenance priority [5].

One of regencies in Indonesia that is developing small dams is Semarang Regency. There are 8 small dams used as objects for determining construction priority that are Dadapayam small dam, Mluweh small dam, Lebak small dam, Pakis small dam, Jatikurung small dam, Gogodalem small dam, Kandangan small dam and Ngrawan small dam.

Research on determining small dams construction priority in Semarang Regency was once carried out by Anjasmoro et al using three methods: cluster analysis, AHP and Weighted Average methods [6]. In the previous study, there were differences in the results between method using technical data and survey data from decision makers. Fuzzy TOPSIS is an ideal solution in accommodating problems of these two different types of data. Fuzzy TOPSIS method accommodates the technical data (numbers and linguistic variables) in form of criteria ranking. While the survey results from the decision makers could be accommodated in the form of criteria weighting. Therefore, in this study, an analysis of Fuzzy TOPSIS method in determining priority of small dams' construction was carried out.

METHODOLOGY

Fuzzy Membership Function

Fuzzy logic is a method introduced by Zadeh in 1965. Fuzzy logic plays a role to accommodate variables that are very complex and cannot be explained quantitatively or often called linguistic variable [7]. In this study, the data that we used consisted of physical data and survey data from decision-maker. These kinds of data tend to have characteristics of linguistic variables and human assessments that difficult to quantify. Therefore, fuzzy logic has an important role in assisting analysis [8].

Fuzzy logic is the development of definite pattern logic or Boolean logic. In Boolean logic, the membership value only has two possibilities, 0 and 1 or member and not member. While the fuzzy membership value has an interval between 0 and 1. This causes fuzzy logic to be suitable for numerating linguistic variables

Fuzzy Membership Function

Fuzzy membership function is a triangle curve that shows the mapping of input data points into its membership value which has an interval between 0 and 1. One way that could be used to get membership value is through a function approach. The triangle curve consists of three parameters (a, b, c) which determine the x coordinate. The fuzzy membership function can be seen as follows:

$$\mu(x) = \begin{cases} 0 & ;\ x \le a \text{ or } x \ge c \\ \frac{x-a}{b-a} & ;\ a \le x \le b \\ \frac{x-c}{b-c} & ;\ a \le x \le c \end{cases} \tag{1}$$

Distance between Two Fuzzy Numbers

If $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ are two fuzzy numbers whose distance will be calculated, then the following equation can be used:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \tag{2}$$

Fuzzy TOPSIS Method

TOPSIS method has a problem solving method by determining the closeness coefficient (CC_i) value of each alternatives. CC_i value represents the distance of each alternatives to the most recommended solution, in this case is fuzzy positive ideal solution (FPIS), and the least recommended solution, in this case is fuzzy negative ideal solution (FNIS) [9]. This CC_i value is used to determine the order of small dams' construction priority. The greater CC_i value of alternatives indicates that the alternative is the closest to the most recommended solution and the farthest from the recommended ideal solution.

Fuzzy TOPSIS method is different from the TOPSIS method that works directly on the basis value of weight of criteria, which is subjective from one judgement. Fuzzy TOPSIS used fuzzy number to accommodate the weight of criteria of many decision makers. Therefore, the value of criteria's weight is more objective [10]. In this study, the weighting for each criterion determined by decision makers by assigning a value between 0 (zero) to 9 (nine) to each criterion. A value of 0 (zero) indicates that the criteria is not important in determining construction priority and the greater value indicates the more important criteria. This value is then converted to a fuzzy number as shown is Table 1.

TABLE 1. Fuzzy Number for Linguistic Variable

Code	Linguistic Variables	Fuzzy Number
0	Not important	(0.00; 0.00; 0.11)
1	Equally important	(0.00; 0.11; 0.22)
2	Between equally important and more important	(0.11; 0.22; 0.33)
3	More important	(0.22; 0.33; 0.44)
4	Between more important and important	(0.33; 0.44; 0.56)
5	Important	(0.44; 0.56; 0.67)
6	Between important and very important	(0.56; 0.67; 0.78)
7	Very important	(0.67; 0.78; 0.89)
8	Between very important and extremely important	(0.78; 0.89; 1.00)
9	Extremely important	(0.89; 1.00; 1.00)

The ranking ($\tilde{x}_{ij}$) and weighting ($\widetilde{w}_j^k$) value for each criterion of decision maker group that has K members can be expressed respectively as:

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}) \tag{3}$$

$$\widetilde{w}_j^k = (a_j'^k, b_j'^k, c_j'^k) \tag{4}$$

Where $i = 1,2,\ldots,m =$ number of alternatives and $j = 1,2,\ldots,n =$ number of criteria. While the average weighting criteria for each criterion can be calculated by

$$\widetilde{w}_j = (a_j', b_j', c_j'), \text{ where} \tag{5}$$

$$a_j' = \min_k\{a_j'^k\},\ b_j' = \frac{1}{K}\sum_{k=1}^{K} b_j'^k,\ c_j' = \max_k\{c_j'^k\} \tag{6}$$

After completing the ranking and weighting criteria, a decision matrix ($\widetilde{D}$) can be expressed by following equation:

$$\widetilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{7}$$

$$\widetilde{W} = (\widetilde{w}_1, \widetilde{w}_2, \ldots, \widetilde{w}_n) \tag{8}$$

Where, $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $\widetilde{w}_j = (a_j', b_j', c_j')$ are a fuzzy function that represents ranking and weights of criterion.

Then we normalized the matrix using linear scale transformation. This method is used to transform various criteria scales into a comparable scale which has range number belong to [0,1]. The normalized matrix ($\tilde{R}$) can be expressed by following equation:

$$\tilde{R} = [\tilde{r}_{ij}]_{m\times n},\ i = 1,2,\ldots,m;\ j = 1,2,\ldots,n \tag{9}$$

In this study, to simplify calculation and avoid normalization of the calculation, then when expressing data, fuzzy number is made in the range between [0,1]. So that $\tilde{r}_{ij} = \tilde{x}_{ij}$ and $\tilde{R} = \widetilde{D}$. This step is an implementation of modified fuzzy procedure using by Saghafian [11].

Then, we calculated the weighted normalized matrix. This method is used to represent differences in the interests of each criterion. The weighted normalized matrix can be expressed by following equation:

$$\tilde{V} = [\tilde{v}_{ij}]_{m\times n},\ i = 1,2,\ldots,m;\ j = 1,2,\ldots,n \text{ ; where} \tag{10}$$

$$\tilde{v}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j = (a''_{ij}, b''_{ij}, c''_{ij}) \quad (11)$$

Then, we can define the FPIS (A^*) and FNIS (A^-). FPIS is a fuzzy value that represents the most recommended solution in this study that is the most prioritized alternative in the construction of small dams. While, FNIS is a fuzzy value that represents the least recommendation solution, or the last priority in the construction of small dams [10]. In this study, modifications were made in determining FPIS and FNIS. If the criteria is benefit attributes then FPIS is the maximum value of c''_{ij} and FNIS is the minimum value of a''_{ij}. Whereas, if the criteria is cost attributes then FPIS is the minimum value of a''_{ij} and FNIS is the maximum value of c''_{ij}. The FPIS and FNIS matrix can be expressed by following equation:

$$A^* = (\tilde{v}_1{}^*, \tilde{v}_2{}^*, \dots, \tilde{v}_n{}^*) \text{ ; where} \quad (12)$$

$$\tilde{v}_j{}^* = \max_i\{c''_{ij}\};\ j \in B \quad (13)$$

$$\tilde{v}_j{}^* = \min_i\{a''_{ij}\};\ j \in C \quad (14)$$

And,

$$A^- = (\tilde{v}_1{}^-, \tilde{v}_2{}^-, \dots, \tilde{v}_n{}^-) \text{ ; where} \quad (15)$$

$$\tilde{v}_j{}^- = \max_i\{c''_{ij}\};\ j \in C \quad (16)$$

$$\tilde{v}_j{}^- = \min_i\{a''_{ij}\};\ j \in B \quad (17)$$

Then the distance of each alternatives to FPIS and FNIS is calculated by using the distance between two fuzzy number equations. Distance between alternative and FPIS can be calculated by following equation:

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j{}^*) \text{ ; } i = 1,2,\dots,m \quad (18)$$

Distance between alternative and FNIS can be calculated by this following equation:

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j{}^-) \text{ ; } i = 1,2,\dots,m \quad (19)$$

Then, we could calculate the closeness coefficient (CC_i) using this following equation:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*} \text{ , } i = 1,2,\dots,m \quad (20)$$

CC_i value represents the distance of each alternatives to the most recommended solution, in this case is FPIS, and the least recommended solution, in this case is FNIS [12]. This CC_i value is used to determine the ranking order of all alternatives of small dam. The greater CC_i value of an alternatives indicates that the alternative is the most recommended solution [13].

RESULT AND DISCUSSION

The data used in this study are primary and secondary data. Primary data were survey data from 20 experts which in this study were called decision makers (DM1, DM2, DM3,..., DM20). Secondary data used in this study was the technical aspect data of small dams. Eight small dams have been studied which are then called alternatives, that is Dadapayam (A1), Mluweh (A2), Lebak (A3), Pakis (A4), Jatikurung (A5), Gogodalem (A6), Kandangan (A7) dan Ngrawan (A8). The technical data of small dams which are then called criteria can be seen in Table 2. There are 7 criteria used in this study. Based on the research results of Anjasmoro et al, the technical aspect that influence the construction of small dams in Semarang Regency are [6]:

1. Vegetation in inundation area (C1)
2. Volume of material embankment (C2)
3. Land acquisition area (C3)
4. Live storage (C4)
5. Reservoir lifetime (C5)
6. Water cost (C6)

7. Access road to dam's site (C7)

TABLE 2. Technical Aspect for Alternative A1, A2, A3, A4, A5, A6, and A7

Alternatives	C1	C2	C3	C4	C5	C6	C7
A1	Rain fed	7,280.00	4.2	538,922.4	57	30,333.00	Footpath
A2	Forest	196,390.00	2.2	3,172,333.3	113	8,322.59	Ground road
A3	Rain fed	99,140.00	2.4	783,975.8	57	8,335.12	Footpath
A4	Rain fed	11,430.00	3.4	1,346,651.1	57	10,092.48	Footpath
A5	Forest	29,280.00	5.3	39,039.7	10	375,650.85	Footpath
A6	Forest	54,722.35	7.3	318,778.0	63	74,434.54	Footpath
A7	Field	46,406.30	2.8	35,907.0	2	549,291.92	Footpath
A8	Field	28,740.00	4.3	18,750.0	22	858,700.26	Ground road

The following steps are used to determine the construction priority of small dams in Semarang Regency using Fuzzy TOPSIS method:

1. Define each criterion and represent as fuzzy membership function. Ranking of each criterion can be seen in Table 3, 4 and 5.

TABLE 3. Ranked for Criteria C1, C2, C3 and C4

C1	C2	C3	C4	Fuzzy Number
Forest	160,000 $m^3 \le X < 200,000\ m^3$	$X \ge 7.5$ Ha	$X \ge 1{,}500{,}000\ m^3$	(0.75, 1.00, 1.00)
Shrubs	120,000 $m^3 \le X < 160,000\ m^3$	6 Ha $\le X <$ 7.5 Ha	750,000 $m^3 \le X < 1{,}500{,}000\ m^3$	(0.50, 0.75, 1.00)
Field	80,000 $m^3 \le X < 120,000\ m^3$	4.5 Ha $\le X <$ 6 Ha	500,000 $m^3 \le X < 750{,}000\ m^3$	(0.25, 0.50, 0.75)
Rain fed	40,000 $m^3 \le X < 80,000\ m^3$	3 Ha $\le X <$ 4.5 Ha	250,000 $m^3 \le X < 500{,}000\ m^3$	(0.00, 0.25, 0.50)
Rural area	$X < 40{,}000\ m^3$	1.5 Ha $\le X <$ 3 Ha	$X < 250{,}000\ m^3$	(0.00, 0.00, 0.25)

TABLE 4. Ranked for Criteria C5 and C6

C5	C6	Fuzzy Number
X ≥100 days	X ≥ Rp40,0000.00	(0.75, 1.00, 1.00)
80 days ≤ X < 100 days	Rp30,000.00 ≤ X < Rp40,000.00	(0.50, 0.75, 1.00)
60 days ≤ X < 80 days	Rp20,000.00 ≤ X < Rp30,000.00	(0.25, 0.50, 0.75)
40 days ≤ X < 60 days	Rp10,000.00 ≤ X < Rp20,000.00	(0.00, 0.25, 0.50)
X < 40 days	X < Rp10,000.00	(0.00, 0.00, 0.25)

TABLE 5. Ranked for Criteria C7

C7	Fuzzy Number
Pavement road	(0.67, 1.00, 1.00)
Ground road	(0.33, 0.67, 1.00)
Footpath	(0.00, 0.33, 0.67)
No road	(0.00, 0.00, 0.33)

2. Calculate the weighting value of each criterion. Weighting value for each criterion is calculated using Eq. (5), (6) and (8). The results could be seen in Table 6. Weighting value of each criterion depends on scale priority of decision makers. The greater weighting value indicates that the criteria has the highest priority scale.
3. Rank criteria of each alternative according to Tables 3, 4 and 5. Then create a fuzzy decision matrix using Eq. (7) as seen in Table 6.

TABLE 6. Fuzzy Decision Matrix and Weight Value of Criteria

	C1	C2	C3	C4	C5	C6	C7
A1	(0.00, 0.25, 0.50)	(0.00, 0.00, 0.25)	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.33, 0.67)
A2	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.00, 0.00, 0.25)	(0.75, 1.00, 1.00)	(0.75, 1.00, 1.00)	(0.00, 0.00, 0.25)	(0.33, 0.67, 1.00)
A3	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)	(0.00, 0.00, 0.25)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.00, 0.25)	(0.00, 0.33, 0.67)
A4	(0.00, 0.25, 0.50)	(0.00, 0.00, 0.25)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.00, 0.33, 0.67)
A5	(0.75, 1.00, 1.00)	(0.00, 0.00, 0.25)	(0.25, 0.50, 0.75)	(0.00, 0.00, 0.25)	(0.00, 0.00, 0.25)	(0.75, 1.00, 1.00)	(0.00, 0.33, 0.67)

A6	(0.75, 1.00, 1.00)	(0.00, 0.25, 0.50)	(0.50, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.25, 0.50, 0.75)	(0.75, 1.00, 1.00)	(0.00, 0.33, 0.67)
A7	(0.25, 0.50, 0.75)	(0.00, 0.25, 0.50)	(0.00, 0.00, 0.25)	(0.00, 0.00, 0.25)	(0.00, 0.00, 0.25)	(0.75, 1.00, 1.00)	(0.00, 0.33, 0.67)
A8	(0.25, 0.50, 0.75)	(0.00, 0.00, 0.25)	(0.00, 0.25, 0.50)	(0.00, 0.00, 0.25)	(0.00, 0.00, 0.25)	(0.75, 1.00, 1.00)	(0.33, 0.67, 1.00)
W	(0.10, 0.34, 0.70)	(0.00, 0.08, 0.40)	(0.10, 0.37, 0.60)	(0.00, 0.27, 0.50)	(0.10, 0.31, 0.50)	(0.00, 0.30, 0.60)	(0.10, 0.38, 0.70)

4. Create a fuzzy weighted normalized decision matrix using Eq. (10) and (11) as seen in Table 7.

TABLE 7. Fuzzy Weighted Normalized Decision Matrix

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
A1	(0.00, 0.09, 0.35)	(0.00, 0.00, 0.10)	(0.00, 0.09, 0.30)	(0.00, 0.14, 0.38)	(0.00, 0.08, 0.25)	(0.00, 0.23, 0.60)	(0.00, 0.13, 0.47)
A2	(0.08, 0.34, 0.70)	(0.00, 0.08, 0.40)	(0.00, 0.00, 0.15)	(0.00, 0.27, 0.50)	(0.08, 0.31, 0.50)	(0.00, 0.00, 0.15)	(0.03, 0.25, 0.70)
A3	(0.00, 0.09, 0.35)	(0.00, 0.04, 0.30)	(0.00, 0.00, 0.15)	(0.00, 0.20, 0.50)	(0.00, 0.08, 0.25)	(0.00, 0.00, 0.15)	(0.00, 0.13, 0.47)
A4	(0.00, 0.09, 0.35)	(0.00, 0.00, 0.10)	(0.00, 0.09, 0.30)	(0.00, 0.20, 0.50)	(0.00, 0.08, 0.25)	(0.00, 0.00, 0.15)	(0.00, 0.13, 0.47)
A5	(0.08, 0.34, 0.70)	(0.00, 0.00, 0.10)	(0.03, 0.19, 0.45)	(0.00, 0.00, 0.13)	(0.00, 0.00, 0.13)	(0.00, 0.30, 0.60)	(0.00, 0.13, 0.47)
A6	(0.08, 0.34, 0.70)	(0.00, 0.02, 0.20)	(0.05, 0.28, 0.60)	(0.00, 0.07, 0.25)	(0.03, 0.16, 0.38)	(0.00, 0.30, 0.60)	(0.00, 0.13, 0.47)
A7	(0.03, 0.17, 0.53)	(0.00, 0.02, 0.20)	(0.00, 0.00, 0.15)	(0.00, 0.00, 0.13)	(0.00, 0.00, 0.13)	(0.00, 0.30, 0.60)	(0.00, 0.13, 0.47)
A8	(0.03, 0.17, 0.53)	(0.00, 0.00, 0.10)	(0.00, 0.09, 0.30)	(0.00, 0.00, 0.13)	(0.00, 0.00, 0.13)	(0.00, 0.30, 0.60)	(0.00, 0.13, 0.47)

5. Define FPIS (A^*) and FNIS (A^-) using Eq. (12) and (15) as follow:
   $A^* = [(0.7, 0.7, 0.7); (0, 0, 0); (0, 0, 0); (0.5, 0.5, 0.5); (0.5, 0.5, 0.5); (0, 0, 0); (0.7, 0.7, 0.7)]$
   $A^- = [(0,0,0); (0.4, 0.4, 0.4); (0.6, 0.6, 0.6); (0, 0, 0)(0, 0, 0); (0.6, 0.6, 0.6); (0, 0, 0);]$

6. Calculate the distance of each alternatives from FPIS and FNIS using Eq. (18) and (19). The results can be seen in Table 8, 9 and 10. If $\boldsymbol{d_i}^*$ is greater than $\boldsymbol{d_i}^-$ then the alternative is closer to the most recommended solution. While, if $\boldsymbol{d_i}^*$ is smaller than $\boldsymbol{d_i}^-$ then the alternative is closer to the least recommended solution.

TABLE 8. Distance of eight alternatives from FPIS

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
d(A1,A*)	0.57	0.06	0.18	0.36	0.40	0.37	0.54
d(A2,A*)	0.42	0.24	0.09	0.32	0.27	0.09	0.46
d(A3,A*)	0.57	0.17	0.09	0.34	0.40	0.09	0.54
d(A4,A*)	0.57	0.06	0.18	0.34	0.40	0.09	0.54
d(A5,A*)	0.42	0.06	0.28	0.46	0.46	0.39	0.54
d(A6,A*)	0.42	0.12	0.38	0.41	0.35	0.39	0.54
d(A7,A*)	0.51	0.12	0.09	0.46	0.46	0.39	0.54
d(A8,A*)	0.51	0.06	0.18	0.46	0.46	0.39	0.46

TABLE 9. Distance of eight alternatives from FNIS

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
d(A1,A-)	0.21	0.37	0.49	0.23	0.15	0.41	0.28
d(A2,A-)	0.45	0.30	0.55	0.33	0.34	0.55	0.43
d(A3,A-)	0.21	0.32	0.55	0.31	0.15	0.55	0.28
d(A4,A-)	0.21	0.37	0.49	0.31	0.15	0.55	0.28
d(A5,A-)	0.45	0.37	0.42	0.07	0.07	0.39	0.28

d(A6,A⁻)	0.45	0.34	0.37	0.15	0.23	0.39	0.28
d(A7,A⁻)	0.32	0.34	0.55	0.07	0.07	0.39	0.28
d(A8,A⁻)	0.32	0.37	0.49	0.07	0.07	0.39	0.43

TABLE 10. Closeness Coefficient for Eight Alternatives

Alternatives		d_i^*	d_i^-	CC_i	**Order**
A1	Dadapayam	2.49	2.13	0.461	4
A2	Mluweh	1.87	2.96	0.612	1
A3	Lebak	2.20	2.37	0.519	3
A4	Pakis	2.18	2.36	0.520	2
A5	Jatikurung	2.61	2.05	0.440	8
A6	Gogodalem	2.60	2.21	0.460	5
A7	Kandangan	2.56	2.02	0.441	7
A8	Ngrawan	2.52	2.14	0.459	6

7. The closeness coefficient (CC_i) was calculated using Eq (20) for each alternatives. The results could be seen in Table 10.
8. Then, based on these closeness coefficients (CC_i), we ranked the construction priority of small dams in Semarang Regency as shown in Table 10. The construction order is ranked from the largest to small CC_i value.

Based on the analysis using Fuzzy TOPSIS method, the largest CC_i values are respectively Mluweh dam, Pakis dam, Lebak dam, Dadapayam dam, Gogodalem dam, Ngrawan dam, Kandangan dam and Jatikurung dam. These results indicate that Mluweh dam has the highest priority in the construction of small dams in Semarang Regency. On the other hand, Jatikurung dam has the lowest priority.

Based on the results of analysis, it was found that the results of Fuzzy TOPSIS method to determine construction priority had similar results to AHP method used by Anjasmoro et al, especially AHP method based on survey data as shown in Table 11 [6]. The difference between results of AHP method based on survey data and Fuzzy TOPSIS method is only on the 6th and 7th ranks, where in previous study, Kandangan dam is on 6th while Ngrawan dam is on 7th. It could be conclude that Fuzzy TOPSIS could be alternative method in determining priority of small dam's construction.

TABLE 11. Results of Analysis Small Dam's Construction Priority using AHP Methods and Fuzzy TOPSIS Methods

Alternatives		**AHP method**		**Fuzzy TOPSIS method**
		Survey data	**Technical data**	
A1	Dadapayam	4	4	4
A2	Mluweh	1	1	1
A3	Lebak	3	6	3
A4	Pakis	2	2	2
A5	Jatikurung	8	8	8
A6	Gogodalem	5	5	5
A7	Kandangan	6	7	7
A8	Ngrawan	7	3	6

CONCLUSION

This study was conducted to determine the construction priority of small dams in Semarang Regency using TOPSIS method. The technical aspects or criteria used are vegetation in inundation area, volume of material embankment, land acquisition area, live storage, lifetime reservoir, water cost and access road to dam's site. To accommodate types of criteria that have linguistic variables, fuzzy logic is used to quantify. Fuzzy logic is then implemented in TOPSIS method so that the best analysis could be obtained.

Priority order of small dam's construction in Semarang Regency is as follows: Mluweh (0.612), Pakis (0.520), Lebak (0.519), Dadapayam (0.461), Gogodalem (0.460), Ngrawan (0.459), Kandangan (0.441) dan Jatikurung (0.440). Based on the results, the first three sequences have the largest live storage and the lowest water cost. Therefore, it could be concluded that the criteria that most influence the determination of small dam's construction priority in Semarang Regency are live storage and water cost.

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