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Fuzzy MADM Method for Decision Support System based on Artificial Neural Network to Water Quality Assessment in Surabaya River

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Abstract

The pollution of the Surabaya River has increased along with the rapid development of the industry in Surabaya. This causes the water quality decreases Surabaya. Surabaya is expected to meet the quality standards of water quality class II. At this time most of the monitoring sites recorded that the quality of water in times of Surabaya exceed the quality standards of raw water quality class II. With details for parameter DO exceed 4 mg / l, BOD exceed 3 mg / l, and COD exceed 25 mg / l. The condition has not been met quality standards of water quality does not occur at any time, but occur at a specific time. However, from the data collected, the current frequency exceeds the quality standards of water quality are very common. Besides, we cannot determine the general conditions in times of Surabaya, because at a time for water quality parameters DO and BOD is to meet water quality standards, while the COD is not fulfilling. So we need a decision support system to see the general picture on eight monitoring sites in Surabaya. In this study begins backpropagation algorithm for classification from the parameters DO, BOD, and COD. Then the results are followed by Fuzzy Multi-Attribute Decision Making (MADM) to get the most polluted sites in times of Surabaya. The results from the this study by using the Simple Additive Weighting Method (SAW), Weighted Product (WP) and TOPSIS showed that location is the 5th most polluted locations to produce value for each 32.2917, 0.1139, and 0.2753.

Keywords: Fuzzy Multi-Attribute Decision Making (MADM), Simple Additive Weighting Method (SAW), Weighted Product (WP), TOPSIS, Backpropagation, Water quality

1. Introduction

Surabaya River is a tributary of the Brantas River located downstream of the watershed has an area of 630.7 km2. Surabaya is then divided into two major rivers to the north with the name Kalimas and the river leading to the east coast called Wonokromo River. Surabaya River is an important source of water for the city of Surabaya. Water on Surabaya are used for various purposes, such as irrigation, drinking water and industrial water. As one of the sources of drinking water, according to the East Java Governor Regulation No. 61 Year 2010 on the Implementation Class Water in Water River, which states that the Surabaya River is expected to meet the quality standards of water quality class II. Ironically, On the several monitoring location on Surabaya River noted that for the parameter DO, BOD and COD are often on the condition exceeds the quality standards of water quality class II. (Syafi'i, 2011)

Before the management to achieve the level of water quality in accordance with established standards, it is necessary to mapping the current conditions on each monitoring location. Data was collected from 2008 to 2013 originated in Perum Jasa Tirta I at monitoring sites on Surabaya River. It is expected from the such data can be done in order to obtain data management quality index of water quality. Following that can produce water quality classification based on parameters DO, BOD, and COD. To resolve these problems. Artificial neural networks are used to obtain the classification of water quality, research that has been done by Liu et al. (2009). In this study, backpropagation is used to determine the estimated grade index monitoring sites based on quality standards. So that the resulting classification of water quality. However, in this study the results of the classification has not been done to the process of decision support systems. So the addition of a decision support system in general is expected to show the sequence of the most polluted location to the location of the nicest in the monitoring sites on Surabaya River.

The research still relevant with this paper by applying artificial neural networks and decision support systems, among others:

In this study, water quality data used in time-series. Irawan et al. (2013) apply the artificial neural network for modeling the time-series data are used as a method of forecasting rainfall with high accuracy. Rainfall forecasting results are used to design a model of crop planting patterns on the island of Lombok.

Whereas research about decision support systems has been widely applied, such as multi criterian decision making Santoso et al. (2013) have conducted research using AHP to model of territorial defense system to resolve violation in Indonesia's marine territory. Then about the SAW, Pratiwi et al. (2014) have conducted research using the SAW to determines the field of study in high school students.

2. Research Methods

The study was conducted by obtaining water quality data which is based on Perum Jasa Tirta I in 2008 to 2013, At 8 point monitoring locations on Surabaya River. Water quality data consists from the parameters BO, BOD, and COD. The data collected is the result of data sampling every month. So that a total of 72 pieces of data for each parameter and the location, which is then processed in time-series.

The stages in this research we divided into two main parts:

- **a.** Stages of classification was preceded by the determination of the quality index of water quality using artificial neural network backpropagation. So the result from the classification on class to know the quality of the water quality on each monitoring location and on time each month on the period of 6 years.
- **b.** Stages of ranking from the most polluted location to the location of the cleanest. Then performed using a decision support system with SAW method, the method WP, and TOPSIS method. Then of the three methods, it will be analyzed from comparison of the three methods.

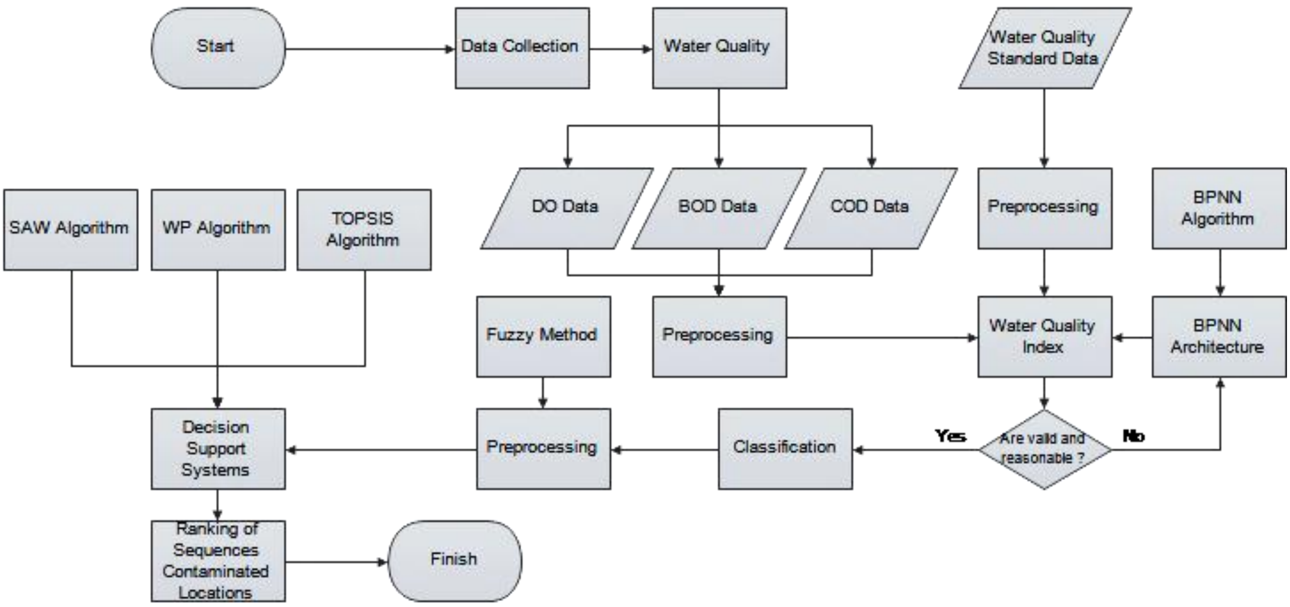

Fig. 1. Flow Chart of Research Procedure.

2.1 Water Quality

2.1.1 Dissolved Oxygen (DO)

Dissolved Oxygen is an important water quality parameters as dissolved oxygen values can indicate the level of contamination or the level of wastewater treatment. The dissolved oxygen will determine the suitability of a particular type of water so as a source of biota (Sunu, 2001). Dissolved oxygen can be derived from the process of photosynthesis and plant water from the atmosphere into the water with limited speed. The concentration of dissolved oxygen is too low will result in fish or other aquatic animals need oxygen will die. Instead of dissolved oxygen concentration is too high also lead to corrosion process faster, because the binding of hydrogen that coats the surface of the metal.

2.1.2 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand indicates the amount of dissolved oxygen is required by living organisms to break down or oxidize the waste material in the water. So the BOD value does not indicate the actual amount of organic matter, but only measures the relative amount of oxygen required to oxidize the waste material. If the high oxygen consumption indicated by the small residual dissolved oxygen, it means that the content of the waste materials that require high oxygen (Fardiaz, 1992).

2.1.3 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand is the amount of oxygen required to oxidize organic substances present in 1 liter of the water sample, in which the oxidizing $K_2\ Cr_2\ O_7$ is used as a source of oxygen. Value of COD is a measure of water pollution by organic substances that can be oxidized through microbiological processes (Alaerts, 1987)

2.2 Backpropagation Model

Backpropagation network model is a learning technique or training supervised learning the most widely used. This method is one method that is excellent in dealing with complex patterns of recognition. In backpropagation network, each unit that is associated with each input layer units in the hidden layer. Each unit in the hidden layer is connected to every unit in the output layer. This network consists from the many layers (multilayer network). When the network is given input pattern as the training pattern, so the pattern to the hidden layer units to be forwarded to the next layer of output units. Then the output layer units will give you a response as artificial neural network output. When the output is not as expected, so output will be propagated backward in the hidden layer and then from the hidden layer to the input layer. (Kusumadewi, 2004)

2.3 Fuzzy Multi-Attribute Decision Making

If the data or information provided, cannot be presented with a complete, uncertainty or inconsistency, then Fuzzy MADM method is the appropriate method to resolve these problems.

The detailed conditions can be solved by Fuzzy MADM method is as follows (Chen, 1997):

a. Information that cannot be counted
b. Incomplete information
c. The information is not clear
d. partial waiver

One of mechanism to resolve the problem of fuzzy MADM is to apply the classical MADM methods that, SAW method, the method WP, and TOPSIS method, which first performed fuzzy data conversion of data into crisp (Chen, 1992).

2.3.1 SAW Method

The basic concept of SAW method is to find a weighted summation from the performance ratings of each alternative on all attributes (Fishburn, 1967). SAW method requires a decision matrix normalization process.

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{Max_i\, x_{ij}}, & if\ \ j = benefit \\ \dfrac{Min_i\, x_{ij}}{x_{ij}}, & if\ \ j = cost \end{cases} \quad (1)$$

r_{ij} is the normalized performance rating from the alternative $A_i\ (i = 1, 2, \dots, m)$ to attribute $C_j\ (j = 1, 2, \dots, n)$. Preference value for each alternative V_i given as:

$$V_i = \sum_{j=1}^{n} w_j r_{ij} \quad (2)$$

That value V_i Larger identified that alternative A_i be selected.

2.3.2 WP Method

WP method is to use multiplication to connect rating attributes, in which each attribute rating should be raised to first with the relevant attribute weights (Yoon, 1989). This process is similar to the process of normalization. Preferences for alternative A_i given as follows.

$$S_i = \prod_{j=1}^{n} x_{ij}^{w_j}\ ; i = 1, 2, \dots, m \quad (3)$$

Where $\sum w_j$ is the rank of positive value to attribute benefit, and to attribute negative worth the cost. Relative preference from the each alternative, is given as:

$$V_i = \frac{\prod_{j=1}^{n} x_{ij}^{w_j}}{\prod_{j=1}^{n} (x_j^*)^{w_j}}; \quad i = 1, 2, \dots, m \quad (4)$$

2.3.3 TOPSIS Method

TOPSIS based on the concept in which the best alternative was selected not only has the shortest distance from the positive ideal solution, but it also has the longest distance from the negative ideal solution (Hwang, 1981).

In general the steps as below TOPSIS method:

a. Making a weighted normalization decision matrix
b. Determining the ideal solution matrix of positive and negative ideal matrix
c. Determine the distance between the value of each alternative with positive ideal solution matrix and the negative ideal solution matrix
d. Specifies the preference value for each alternative.

TOPSIS require performance rating of each alternative A_i on each criterion C_i yang normalize

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}};\ \ i = 1, 2, \dots, m\ \ ; j = 1, 2, \dots n \quad (5)$$

Positive ideal solution A^+ and the negative ideal solution A^- can be determined based on the normalized weight rating y_{ij} as:

$$y_{ij} = w_i r_{ij}\quad ; i = 1, 2, \dots, m\quad ; j = 1, 2, \dots, n$$
$$A^+ = (y_1^+, y_2^+, \dots, y_n^+)$$
$$A^- = (y_1^-, y_2^-, \dots, y_n^-) \quad (6)$$

With

$$y_j^+ = \begin{cases} \max_i y_{ij}\ ; j\ is\ benefit \\ \min_i y_{ij}\ ;\quad j\ is\ cost \end{cases}$$

$$y_j^- = \begin{cases} \max_i y_{ij} \ ; j \text{ is benefit} \\ \min_i y_{ij} \ ; \quad j \text{ is cost} \end{cases} \quad (7)$$

Distance between alternative A_i the positive ideal solution formulated as:

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (y_i^+ - y_{ij})^2} \ ; \quad i = 1, 2, \dots m \quad (8)$$

Distance between alternative A_i the negative ideal solution is formulated as:

$$D_i^- = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_{ij}^-)^2} \ ; \quad i = 1, 2, \dots, m \quad (9)$$

Preference value for each alternative V_i given as:

$$V_i = \frac{D_i^-}{D_i^- + D_i^+}; \quad i = 1, 2, \dots, m \quad (10)$$

Value of V_i is greater indicates that alternative A_i is preferred.

3. Result and Discussion

3.1 Classification by using BPNN

Water quality standards based on the grade of water according to the Government Regulation No. 82 of 2001 Regarding Management of Water Quality and Water Pollution Control

Table 1.
Class Standard Quality for Parameter DO, BOD, and COD.

Parameter	Units	Class			
		I	II	III	IV
DO	mg/liter	6	4	3	0
BOD	mg/liter	2	3	6	12
COD	mg/liter	10	25	50	100

In the training phase with the input layer, which consists of three units, each of which represents a parameter DO, BOD, and COD. Then use as a hidden layer, which consists from the 10 units, and the output layer consisting from the 4 units. (Prihasto, 2014a)

Technically, from the Table 1 are used as inputs to the neural network training stage of backpropagation, and with 4 units as the output layer are respectively defined for class I ={9,1,1,1}, class II={1,9,1,1}, class III={1,1,9,1} and class IV={1,1,1,9}. Architecture that has been built can be illustrated in Fig. 2

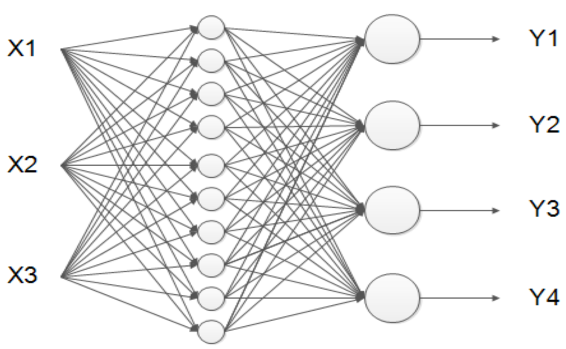

Fig 2. Backpropagation Algorithm Architecture.

By using logsig activation function in the hidden layer and output layer purelin. Then testing as much as 10 times by changing learning rate. The results obtained proved that the architecture that has formed MSE produce a range of less than 0.0001

Table 2
The results from the testing at the stage of training.

Learning Rate	Epoch	MSE	Gradient
0.01	679	0.000942	0.00712
0.02	664	0.000988	0.00724
0.03	664	0.000997	0.0103
0.04	644	0.000956	0.0298
0.05	639	0.000976	0.00716
0.06	652	0.000957	0.00709
0.07	637	0.000989	0.0072
0.08	669	0.000995	0.00723
0.09	638	0.000977	0.0249
0.1	633	0.000957	0.0217

At this stage of simulation used the results of experiments on the stage of training by taking the smallest MSE value, so the use of learning rate = 0,04.
At this stage of the simulation data is used as input data comes from Perum Jasa Tirta I in 2008-2013. With Preprocessing performed under the following conditions

For parameter DO:

- If $(DO \geq 6)$, Then $DO = 1$
- If $(DO < 6) \cap (DO \geq 4)$, Then $DO = 2$
- If $(DO < 4) \cap (DO \geq 3)$, Then $DO = 3$
- If $(DO < 3) \cap (DO \leq 0)$, Then $DO = 4$

For parameter BOD:

- If $(BOD \leq 2)$, Then $BOD = 1$
- If $(BOD > 2) \cap (BOD \leq 3)$, Then $BOD = 2$
- If $(BOD > 3) \cap (BOD \leq 6)$, Then $BOD = 3$
- If $(BOD > 6)$, Then $BOD = 4$

For COD parameter:

- If $(COD \leq 10)$, Then $COD = 1$
- If $(COD > 10) \cap (COD \leq 25)$, Then $COD = 2$
- If $(COD > 25) \cap (COD \leq 50)$, Then $COD = 3$
- If $(COD > 50)$, Then $COD = 4$

From Simulation to all monitoring locations, In Table 3, compiled the number of occurrences (frequency) at which the dominant class of the index for the time span from 2008 to 2013. (Prihasto, 2014b)

Table 3
Results of Simulation Backpropagation to the number of occurrences of the year 2008-2012 in Surabaya.

Class	Canggu Brigde	Jrebeng Bridge	Cangkir Tambangan	Bambe Tambangan
Class I	22	1	0	0
Class II	31	27	18	13
Class III	19	44	54	57
Class IV	0	0	0	2

Class	Karangpil ang	Sepanjang Bridge	Gunungsari Dam	Jagir/Ngagel
Kelas I	0	0	0	0
Kelas II	6	15	19	11
Kelas III	65	53	50	57
Kelas IV	1	4	3	4

3.2 Ordering by using fuzzy MADM

3.2.1 Preprocessing with Fuzzy

In Indonesia, the dry season occurs during April-September and rainy season occurs during October to March. During the dry season, the water discharge in the river becomes very low, thus affecting the process of purification of the pollutants. And the rainy season is very good discharge conditions, it resulted in the purification process for the better. We decided to give the value of the preference weights were lower in the dry season and high preference weights in the rainy season.

Table 4
Decision for Weights References.

Month	Weight Preference
January	Very Good
February	Good
March	Good
April	Medium
May	Medium
June	Bad
July	Bad
August	Medium
September	Medium
October	Good
November	Good
December	Very Good

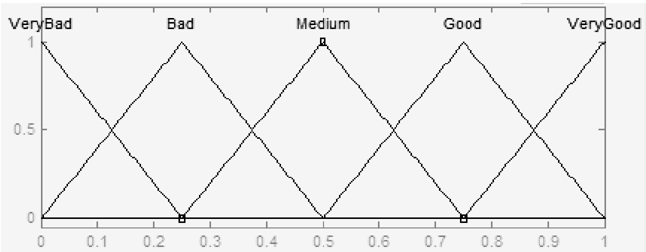

Fig 3. Fuzzy number for weights preference.

The results of the classification at each monitoring location, and then converted into the form of linguistics, then shown into fuzzy numbers.

Table 5
Decision for Weights References.

Classification	Pollutant
Class I	Very Clear
Class II	Clear
Class III	Medium
Class IV	Muddy

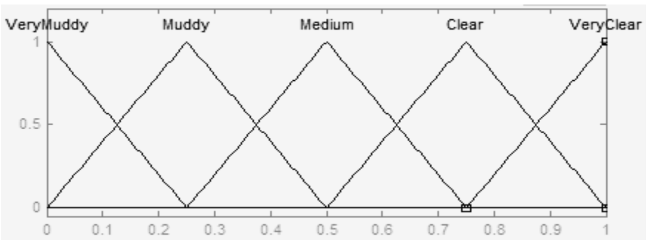

Fig 3. Fuzzy number for classification of pollutant.

3.2.2 Implementation Fuzzy MADM

Results from preprocessing using the fuzzy, then performed the process of decision support system with SAW, WP, and TOPSIS. The results of the implementation shown in Table 6.

Table 6
Result from the decision support system using fuzzy MADM.

Location	SAW	WP	TOPSIS
Canggu Bridge	44.5000	0.1620	0.8654
Jrebeng Bridge	36.5208	0.1302	0.4730
Cangkir Tambangan	34.3750	0.1219	0.3613
Bambe Tambangan	34.0417	0.1200	0.3849
Karangpilang	32.2917	0.1139	0.2753
Sepanjang Bridge	33.4375	0.1174	0.3482
Gunungsari Dam	34.2083	0.1199	0.3404
Jagir/Ngagel	32.4167	0.1148	0.2977

So the sequence starting location heaviest contamination on:

- SAW Method = {Karangpilang → Jagir/Ngagel → Sepanjang Bridge → Bambe Tambangan → Gunungsari Dam → Cangkir Tambangan → Jrebeng Bridge → Canggu Bridge}
- WP Method = {Karangpilang → Jagir/Ngagel → Sepanjang Bridge → Gunungsari Dam → Bambe Tambangan → Cangkir Tambangan → Jrebeng Bridge → Canggu Bridge}
- TOPSIS Method = {Karangpilang → Jagir/Ngagel → Gunungsari Dam → Sepanjang Bridge → Cangkir Tambangan → Bambe Tambangan → Jrebeng Bridge → Canggu Bridge}

4. Conclusion

Backpropagation neural network classification successfully perform well, and with the process followed by the decision support system generated sequence from the most polluted location to the location of the most better. In terms of the application of SAW, WP, and TOPSIS, the three methods tested that did not experience a very significant difference. So the method is very feasible to be implemented in this research.

Stages through which this research is purely academic purposes. With advantages of information generated is accurate enough, and disadvantage is the source of the data obtained is every month, it is better conducted every week or every day

In this research contribute to a general overview of the situation on the river Surabaya. where the latter can be considered in Surabaya city government's policy to make the city of green and clean.

In the future, artificial intelligence and decision support system is still needed to resolving problems in the field of environment, for the development of algorithms in the research or the application of a different scope to be very meaningful

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