Application of Fuzzy AHP and Fuzzy TOPSIS methods for the new normal problem

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Abstract. The government have new program to deal with the pandemic impact of the Coronavirus, which is said with the new normal. The implementation of the new normal itself requires more attention in terms of the readiness of a region to implement the program. Determination of these areas can be done using the Fuzzy Analytical Hierarchy Process (AHP) and fuzzy technique for Order Performance by Similarity to Ideal Solution (TOPSIS) methods. Fuzzy AHP is used to determine the weight of the existing criteria, while Fuzzy TOPSIS is used to determine the safest area and is ready to implement the new normal. The case study for the problem in this paper is Central Java Province, with alternatives districts and cities. The influencing criterias are the number of People Under Surveillance (PeUS), the number of Patient Under Surveillance (PaUS), the number of patients being treated, the number of positive patients who died, and positive patients who recovered. Triangular fuzzy number approach both methods. The results of this study found that 30% of the total number of districts or cities are ready to implement the New Normal program. This study also explain that the higher of the patient number being treated, the less safe an area will be. While the patients number who recover is increasing, then an area will be ready to implement a New Normal program.

1. Introduction
In 2020, the Covid-19 disease outbreak appeared, which made people around the world experienced losses in various fields. The occurrence of a health crisis has an impact on the world economy, which allows an economic slowdown, recession, and even depression [1]. This is also felt by Indonesian citizens who have experienced the impact of this outbreak. So that the government must make the right strategy to overcome two conflicting problems, namely saving many lives with strict quarantine, but on the other hand, it must save the economy from the impact of Covid-19. A strategy that was deemed efficient enough to overcome these problems emerged, namely the new normal program. The new normal is a continuation of the previous government program, namely Large-Scale Social Restrictions, which aims to move the wheels of the economy. The new normal itself can be interpreted as any existing activity run as usual, but still paying attention to the prevailing health protocols [1]. In its application, it requires special attention in declaring an area ready or not in implementing this new normal program. If an area is not yet capable, it results an increase in the number of positive patients with the Covid-19 virus. Therefore, a research was conducted using fuzzy Analytical Hierarchy Process (AHP) and Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) methods to assist in making decisions whether an area is feasible to implement the new normal.

Fuzzy AHP contains several important characteristics such as pairwise comparison, hierarchy, independence and consistency in decision making [2]. The addition of fuzzy in the conventional AHP
method is done to cover the shortcomings of this method, namely when the problem becomes more complex the solution will be less accurate [3]. In Fuzzy AHP, the degree of importance is represented using fuzzy numbers, so that the weighting can be calculated as accurately as possible [4]. Finding the weight value of a criterion using the Fuzzy AHP method has been carried out in several previous studies [5-7]. So that this method can also be used to find the weight of the new normal problem in this study. Then to find the feasibility value of an area deemed feasible to run the New Normal program, we use Fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution). In the Fuzzy TOPSIS method, there are 2 types of alternatives, namely the positive ideal solution and the negative ideal solution, which then looks for the final value closest to the positive ideal solution and furthest from the negative ideal solution [8]. This method can assist decision makers in solving problems and conducting analysis, comparison and ranking of solutions from alternatives [9]. However, the weakness of this method lies in the difference in the weight of each criterion determined by each decision maker [10]. The combination of AHP and Fuzzy TOPSIS methods will be used for the new normal program problem.

In [11], Ren et al. Used the Resistence fuzzy linguistic method on the Z number to assist in the selection of drugs for Covid-19 patients with mild symptoms. In [12], Albahri et al. Conducted a study to help medical personnel determine blood plasma transfusions to treat COVID-19 patients using the ML method to classify blood types and the MCDM method to assist in making the best decisions. In [13], Requia et al. Using the MCDM method to determine the best steps regarding the provision of health facilities for COVID-19 patients in Brazil with criteria such as number of beds, ventilator capacity, capacity for recycled masks and ordinary masks and availability of health workers. In [14] Mishra et al. Using the AHP method to find the Covid vulnerability index in 4 major regions in India by considering social distancing and lockdown. Based on the previous researches, it can be seen that Fuzzy MCDM can be used to assist in making decisions about the COVID-19 problem.

2. Method
Determining a city or district ready to implement the new normal program depends on several things, namely the number of positive patients, recovered patients, dead patients, Patient Under Surveillance (PaUS) and People Under Surveillance (PeUS). The data used were obtained from the corona.jatengprov.go.id website and used data on August 21, 2020. In performing calculations, Microsoft Excel software is used.

2.1. Fuzzy AHP
Fuzzy AHP selected because the addition of fuzzy is useful for achieving a more accurate assessment by making the selection criteria into a fuzzy form [15]. The steps taken are as follows [16,17]:

2.1.1. Step 1. Evaluating the best alternative among the available alternatives by considering the various criteria involved. The selection of the best alternative will be made based on the construction of a hierarchical system

2.1.2. Step 2. Determination of the weight using triangular fuzzy numbers. Use of TFN with reason is intuitively easy for decision makers to use and calculate. In addition, TFN modeling has proven to be an effective way of formulating problems where the available information is subjective and uncertain. AHP fuzzy computation process is explained as follows. The triangular fuzzy number a can be defined by a triplet (l, m, u). The membership function $\mu$ can be defined as follows

$$
\mu^\sim (x) = \begin{cases} 
\frac{x-l}{m-l}, & l \leq x \leq m \\
\frac{u-x}{u-m}, & m \leq x \leq u \\
0, & \text{otherwise}
\end{cases} 
$$

(1)

In this study, we use fuzzy linguistics, "equal", "moderate", "strong", "very strong" and "extremely strong". With the weight values in sequence as follows: (1,1,1); (2,3,4); (4,5,6); (6,7,8); (9,9,9).
2.1.3. Step 3. Specifies weights for the criteria involved. The determination of the weights for the evaluation criteria involves the following steps: 1) A matrix of pairwise comparisons showing the preference of one criterion over another is constructed by including the values judged by the decision makers. Since the value is a linguistic variable, the triangular fuzzy number triplet is inputted. 2) The synthetic pairwise comparison matrix calculated using the geometric mean method \( r_i \) is defined as

\[
\eta_i = (a_{ij}^1 \times a_{ij}^2 \times \ldots \times a_{ij}^n)^{1/n}
\]  

(2)

2.1.4. Step 4. Weights for each criterion are determined. This is done by normalizing the matrix

\[
\omega_i = r_i \times (r_1 + r_2 + r_3 + \ldots + r_n)^{-1}
\]  

(3)

2.2. Fuzzy TOPSIS

Fuzzy TOPSIS method is used to get a near perfect solution of cryptic problems so that the best steps can be applied to find a solution [15]. In this method, the solution is divided into two ideal solutions, namely positive ideal solution and a negative ideal solution. A positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criterion, while a negative ideal solution is a solution that maximizes the cost criterion and minimizes the benefit criterion [18]. The calculation steps using of Fuzzy TOPSIS method are as follows [8,18,19]:

2.2.1. Step 1. Determine suitable alternatives, to evaluate criteria and establish a group of decision makers. Assume that there are alternatives, criteria and decision makers. 

2.2.2. Step 2. Determine the appropriate linguistic variables for each criterion weight \((\tilde{w}_j = l_{ij}, m_{ij}, u_{ij})\) and linguistic rankings for alternatives related to the variable \(Xij\) as a Triangular Fuzzy Number (TFN).

2.2.3. Step 3. Combine the criteria weights to obtain the aggregate fuzzy weights \(\tilde{w}_j\) of the criteria \(C_j\) and get the aggregate fuzzy rank of the alternatives \(A_i\) with \(C_i\) criteria that have been evaluated using Fuzzy AHP.

\[
\tilde{X}_{ij} = \frac{1}{k} \left[ \tilde{X}_{i1}^1 + \tilde{X}_{i2}^2 + \ldots + \tilde{X}_{in}^k \right] \quad ; i = 1, 2, \ldots, m; j = 1, 2, \ldots, n
\]  

(4)

\[
\tilde{W}_j = \frac{1}{k} \left[ \tilde{W}_j^1 + \tilde{W}_j^2 + \ldots + \tilde{W}_j^k \right] \quad ; j = 1, 2, \ldots, n
\]  

(5)

2.2.4. Step 4. Perform fuzzy decision matrix construction.

\[
\tilde{D} = \begin{bmatrix}
\tilde{X}_{11} & \tilde{X}_{12} & \ldots & \tilde{X}_{1n} \\
\tilde{X}_{21} & \tilde{X}_{22} & \ldots & \tilde{X}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\tilde{X}_{m1} & \tilde{X}_{m2} & \ldots & \tilde{X}_{mn}
\end{bmatrix}
\] \quad \tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n]

(6)

2.2.5. Step 5. Normalizing the fuzzy decision matrix. The normal fuzzy decision matrix is denoted by \(R\) using the following formula.

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

(7)

The formula can be written in detail as follows:

\[
\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_i^j}, \frac{m_{ij}}{u_i^j}, \frac{u_{ij}}{u_i^j}\right), u_i^j = max u_{ij}
\]  

(8)

\[
\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_i^j}, \frac{m_{ij}}{u_i^j}, \frac{u_{ij}}{u_i^j}\right), u_i^j = min l_{ij}
\]  

(9)
2.2.6. **Step 6.** Normalize the weighting of the fuzzy decision matrix.

\[ V = \left[ \tilde{V}_{ij} \right]_{m \times n}, i = 1, 2, ..., m; j = 1, 2, ..., n \]  

Where \( \tilde{V}_{ij} = \tilde{r}_{ij}, \tilde{w}_j, i = 1, 2, ..., m; j = 1, 2, ..., n \)

2.2.7. **Step 7.** Finding the value of the fuzzy positive ideal solution (\( S^+ \)) and fuzzy negative ideal solution (\( S^- \)).

\[
S^+ = (\tilde{V}_{1}^+, \tilde{V}_{2}^+, ..., \tilde{V}_{m}^+) \\
S^- = (\tilde{V}_{1}^-, \tilde{V}_{2}^-, ..., \tilde{V}_{n}^-)
\]

Where \( \tilde{V}_{j}^+ = \max \{v_{ij3} \} \) and \( \tilde{V}_{j}^- = \min \{v_{ij1} \} \) with \( \tilde{V}_j \) represents the weighting normalization for TFN.

\[ i = 1, 2, ..., m; j = 1, 2, ..., n \]

2.2.8. **Step 8.** Perform distance calculations for each alternative from the fuzzy positive ideal solution (\( d_i^+ \)) and fuzzy negative ideal solution (\( d_i^- \)).

\[
d(A_1, A_2) = \frac{1}{3} \left[ (l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2 \right] \\
d_i^+ = \sum_{j=1}^{n} d(\tilde{V}_{ij}, \tilde{V}_{j}^+), i = 1, 2, ..., m \\
d_i^- = \sum_{j=1}^{n} d(\tilde{V}_{ij}, \tilde{V}_{j}^-), i = 1, 2, ..., m
\]

2.2.9. **Step 9.** Calculates the Closeness Coefficient (CC_i) and find a rating for each alternative.

\[
CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, i = 1, 2, ..., m
\]

Based on the value of the proximity coefficient for each alternative, the highest coefficient of proximity is the best solution of this method.

### 3. Results and Discussion

In this discussion, data processing will be carried out using the Fuzzy Analytical Hierarchy Process method to find the weight value of each criterion. By using Step 1 in the Fuzzy AHP method, the criteria used will be determined, namely People Under Surveillance (PeUS), Patient Under Surveillance, Positive Healing Patients, Positive Patients Died and Patients Positive in care (treated). This is done so that the value of the three variables has an equivalent limit.

\[
Heal = \frac{\text{Number of Heal}}{\text{Total Positive Patients}} \\
Dead = \frac{\text{Number of Dead}}{\text{Total Positive Patients}} \\
Treated = \frac{\text{Number of Treated}}{\text{Total Positive Patients}}
\]

With the total positive patients is the number of patients recovered, patients died and patients were treated. It is followed by determining the weight value using TFN and fuzzy linguistics in Step 2. In Step 3, a pairwise comparison is made for each criterion with the results shown in Table 1.
Table 1. Pairwise Comparison of Each Criterion

| Criteria | PeUS       | PaUS       | Heal       | Died       | Patients |
|----------|------------|------------|------------|------------|----------|
| PeUS     | (1,1,1)    | (2,3,4)    | (0.16,0.2,0.25) | (0.25,0.33,0.5) | (4,5,6)  |
| PaUS     | (0.25,0.33,0.5) | (1,1,1)    | (0.125,0.14,0.16) | (0.16,0.2,0.25) | (2,3,4)  |
| Heal     | (4,5,6)    | (6,7,8)    | (1,1,1)    | (2,3,4)    | (9,9,9)  |
| Died     | (2,3,4)    | (4,5,6)    | (0.25,0.33,0.5) | (1,1,1)    | (6,7,8)  |
| Patients | (0.16,0.2,0.25) | (0.25,0.33,0.5) | (0.11,0.11,0.11) | (0.125,0.14,0.16) | (1,1,1)  |

Then find the value of $r_i$ using (2). Then in Step 4 we calculate look for the weight for each criterion, by substituting the value of $r_i$ to equation (3). So that we get the weight value in Table 2.

Table 2. Weights of Each Criteria for Fuzzy AHP Calculation Results

| Criteria | Weights          |
|----------|------------------|
| PeUS     | (0.088,0.128,0.193) |
| PaUS     | (0.044,0.062,0.094) |
| Heal     | (0.372,0.506,0.69) |
| Died     | (0.182,0.268,0.377) |
| Patients | (0.024,0.032,0.045) |

After getting the weighted value, the calculation will be continued using Fuzzy TOPSIS to find a safe area or ready to implement the New Normal program. The data to be used is data on Covid-19 patients on August 21, 2020 and there are 35 alternatives, namely districts or cities in Central Java Province. The first step is to determine Fuzzy linguistics for each criterion and its weight value. In this case I use 5 levels, namely Very low (1,1,3), Low (1,3,5), Medium (3,5,7), High (5,7,9), and Very High (7,9,9). After knowing the value of each alternative, it will be continued by normalizing the data using (7). Before carrying out normalization, first determine the cost and benefit of the criteria used. The criteria included in the cost are PeUS, PaUS, and positive patients who are still being treated using normalization (9), while the benefit criteria are positive patients who have recovered and positive patients who have died were normalized using (8).

After obtaining the value of each alternative normalized result, we multiply the weight of the AHP calculation with the value of the normalization result as in (10). Then the ideal solution will be searched for positive and negative ideal solutions for each criterion. The positive ideal solution ($S^+$) is the highest value contained in a criterion, while the negative ideal solution ($S^-$) is the lowest value of the criterion. The next step is to find a distance from the positive ideal solution to the alternative and the negative ideal solution to the alternative using (13). In this case, the resulting distance is not in the form of triplets, but in the form of real numbers. Furthermore, we calculate the Closeness Coefficient (CC) value as a result of the final decision using (14). CC calculation results can be seen in Table 3.

From Table 3, it can be seen that several alternatives have a value of $CC = 1$ that mean the district or city is ready to implement the New Normal program with the necessary health protocols. For example, one of the district that is ready is Magelang. Magelang has a number of positive covid patients who are still being treated with a value of 0.235 or as many as 46 patients out of a total of 226 positive patients, as well as PeUS as many as 0 people and PaUS as many as 9 people. For values below 1 but still above 0.8, they are still considered ready but need more supervision. Meanwhile, for values below 0.8, it is not recommended to implement the new normal program because the number of PeUS, PaUS and treated patients is still large based on available data. The district with the lowest CC value is Purworejo. This is due to the large value of the criteria for treated patients, namely 0.5862 or as many as 136 patients out of a total of 232 patients, and PeUS as many as 0 and PaUS as many as 17. normal. However, apart from these criteria, the implementation of the new normal also depends on the number of recovered patients, which is a consideration that a district or city is able to overcome the Covid-19 pandemic.
Table 3. CC Value

| District/City | CC Value | District/City | CC Value | District/City | CC Value |
|---------------|----------|---------------|----------|---------------|----------|
| Kota Semarang | 0.7336   | Purworejo     | 0.397    | Batang        | 0.63     |
| Jepara        | 1        | Magelang      | 1        | Pati          | 0.6415   |
| Demak         | 0.6717   | Blora         | 0.6414   | Wonogiri      | 1        |
| Kudus         | 0.4598   | Karanganyar   | 1        | Cilacap       | 1        |
| Kendal        | 0.5531   | Klaten        | 0.8543   | Pekalongan    | 0.8344   |
| Grobogan      | 0.6717   | Sragen        | 0.6414   | Purbalingga   | 1        |
| Sukoharjo     | 1        | Rembang       | 0.8544   | Kota Magelang | 0.8543   |
| Semarang      | 0.8344   | Kebumen       | 1        | Tegal         | 0.8344   |
| Temanggung    | 1        | Pemalang      | 0.6415   | Brebes        | 0.8345   |
| Boyolali      | 0.8344   | Wonosobo      | 0.8345   | Kota Pekalongan | 0.8344 |
| Kota Surakarta| 1        | Banjarnegara  | 0.8344   | Kota Tegal    | 1        |
| Banyumas      | 1        | Kota Salatiga | 0.8543   |               |          |

4. Conclusion
This research provides information about districts or cities that are feasible to implement the new normal program using the Fuzzy AHP and Fuzzy TOPSIS methods. According to the TOPSIS Fuzzy calculation, using COVID-19 patient data on August 21, 2020, around 30% of all districts or cities in Central Java Province are ready to implement the New Normal Program. Based on the result, we concluded that the greater the value of the criteria for being treated patients will make the district or city not ready to implement the new normal program. Meanwhile, the greater the value of the recovery criteria, the more prepared a district or city will be to implement the new normal program. This is because the number of recovered patients shows that the local government and medical team have the right facilities and methods to treat patients who are positive for the Coronavirus. The weakness of this research is that the weight used still comes from the method, and has not been officially determined by the government or health institutions.

References
[1] Muhyuddin 2020 Indones. J. Develop. Plan. 4 240-252
[2] Ortiz-Barrios M, Gul M, Lopez-Meza P and Yucesan M 2020 Inter. J. Disaster Risk Reduct. 49 101748
[3] Chand M and Avikal S 2015 An MCDM based approach for purchasing a car from Indian car market ed IEEE (India: SCES) p 1-4
[4] Lyu H M, Zhou W H, Shen S L and Zhou A N 2020 Sustain. Cities Soc. 56 102103
[5] Singh A K, Avikal S, Kumar N K C, Kumar M and Thakura P 2020 A fuzzy-AHP and M-TOPSIS based approach for selection of composite materials used in structural applications vol 26 (India: Elsevier) 3119-3123
[6] Sirisawat P and Kiatcharoenpol T 2018 Comput. Ind. Eng. 117 303-318
[7] Palczewski K and Salabun W 2019 The fuzzy TOPSIS applications in the last decade vol 159 (Poland: Elsevier) 2294-2303
[8] Rouyendegh B D and Saputro T E 2014 Supplier selection using integrated fuzzy TOPSIS and MCGP: a case study vol 116 (Turkey:Elsevier) 3957-3970
[9] Chang H K, Liou J C and Chen W W 2012 J. Coast. Res. 28 369-374
[10] Biderci H and Canbaz B 2019 Ergonomic room selection with intuitive fuzzy TOPSIS method vol 158 (Turkey: Elsevier) 58-67
[11] Ren Z, Liao H and Liu Y 2020 Comput. Ind. Eng. 145 106517
[12] Albahri O S, Al-Obaidi J R, Zaidan A A, Albahri A S, Zaidan B B, Salih M M, Qays A, Dawood K A, Mohammed R T, Abdulkareem K H, Aleessa A M, Alamoodi A H, Chyad M A and Zulkifli C Z 2020 Comput. Methods Programs Biomed. 196 105617
[13] Requia W J, Kondo E K, Adams M D, Gold D R and Struchiner C J 2020 Sci. Tot. Environ. 730
139144

[14] Mishra S V, Gayen A and Haque S M 2020 *Habitat Int.* **103** 102230

[15] Dadras M, Shafri H Z M, Ahmad N, Pradhan B, and Safarpour S 2014 *J. Urban Environ. Eng.* **8** 11-27

[16] Vinodh S, Prasanna M and Prakash N H 2014 *Appl. Math. Model.* **38** 4662-4672

[17] Khan A A, Shameem M, Kumar R R, Hussain S and Yan X 2019 *Appl. Soft Comput. J.* **83** 105648

[18] Wang Y M and Elhag T M 2006 *Expert Syst. Appl.* **31** 309-319

[19] Lee G, Min B I and Jun K S 2016 *Coastal Educ. Res. Found.* **2** 1172-1176