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Fuzzy TOPSIS Approach for Ranking Flood Factors in Kedah

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Abstract
Flood is a common natural disaster in Malaysia. This phenomenon is mainly triggered by continuous heavy rainfall causing the water in a river or sea to cross the danger level, resulting to flood. For instance, if the drainage system is not functioning well due to blockage, it is more likely for a flood to occur, causing damages to buildings, bridges, farms, roads, automobiles, and houses. Slope of basin and type of soil are also contributing factors to causes of flood. The main objective of this research is to use Fuzzy TOPSIS to classify the most significant factors in the frequency of floods in Kedah. This method is able to select and rank the factors that cause flood for all the districts in Kedah. To obtain the data, an interview was conducted with an expert from the Department of Irrigation and Drainage Kedah. The result of this study is obtained after the closeness coefficient is calculated. The first ranking is selected as the highest proximity coefficient value that is closest to Fuzzy Positive Ideal Solution. From this study, rainfall is indicated as the most important factor followed by drainage system, type of soil and lastly, slope of basin. The result can be used by Department of Irrigation and Drainage Kedah to make early preparation and prevention plans to tackle the phenomenon.
Keywords: Fuzzy TOPSIS, Fuzzy Positive Ideal Solution, Rainfall, Drainage System, Slope of Basin

Introduction

Flooding is the most damaging type of natural disaster that strikes humans and their livelihoods around the world. Flood can be defined as rising or overflowing of water to the dry land. This is mainly triggered by continuous heavy rainfall causing the water level in a river or sea to surpass the danger level, resulting to flood. In Malaysia, rainy or monsoon season refers to the annual rainfall occurring in a long period of time normally from November to March. If the drainage system is not well maintained, heavy rains during this season can cause flood, causing damage to buildings, bridges, farms, roads, automobiles, and houses. Flood comes in a variety of depths ranging from one inch to several feet over a period of time (a few minutes, hours, days or even weeks). A flood occurring in a short period of time without any warning is referred to as flash flood (Norbiato et al., 2008). Flash flood typically causes the biggest loss of human life compared to other types of flood.

Kedah is one of states that faces flood, though relatively lesser than the East Coast areas such as Kelantan, Terengganu, and Pahang. One of the factors contributing to flood in some areas of Kedah is when the water in several rivers reach the danger level. This happened in Sungai Kuala Nerang where the water is 2m above the danger level (Kaur & Majid, 2010). The flood occurs since the water from river overflow to the road and rice field. Consequently, this will result the economic loss when the paddy is unable to be produced due to the flood. Similarly, heavy rain is another factor contributing to flood. When the heavy rain occurs followed by the non-functional drainage system in Kedah, it causes more rapid flood in the affected areas. It is important to identify the flood factors to make people more aware of the signs of incoming flood.

Therefore, this study sought to determine the most significant factor of flood incidence in Kedah and to use Fuzzy Technique for Order Preference by Similarity to Ideal Situation (TOPSIS) to rank the flood factors based on all the district in Kedah. The best factor in position stability was evaluated by this approach, since it relates to different weighting criteria and several sub-criteria (Azizi et al., 2015). The data was collected by interviewing an expert from Department of Irrigation and Drainage Kedah.

Related Works

A common approach used for Multiple-Criteria Decision Making (MCDM) is the Fuzzy Technique for Order of Choice by Similarity to Ideal Solution (TOPSIS). In this strategy, Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) typically have two ideal solutions. FPIS is made up of all the best values, while FNIS is made up of the worst values. The optimal alternative can be defined as the one with the shortest FPIS distance and the longest FNIS distance (Wang & Lee, 2007).

In compliance with Zeyaeyan et al. (2017), the classification of rainfall alerts is the TOPSIS system al which intended to assess the alert level. Through the use of long-term precipitation data, this research focused on defining different alert levels in north-west Iran. The result shows that for each station of warning level, the rainfall has been defined with respect to these grades. The best rank was calculated in this study from the lowest value of the alarm level, while the worst rank was obtained from the highest.

Sodhi and T.V. (2012) stated that the Fuzzy TOPSIS approach was studied to decide which laptop to buy from two people on the basis of certain parameters. In this research, there are four parameters and two alternatives that have been used. Fuzzy TOPSIS is the technique that will assist the two individuals to pick and choose the best choices to purchase a laptop. The researchers find that the value of alternatives' near coefficient of closeness is near to each other, which is and. The best options have the highest value a.

The above result is backed by research from Fu (2008) that proposed a fuzzy optimization method based on MCDM. The investigator applied fuzzy TOPSIS to the reservoir flood control operation. The goal of this analysis was to decide the best alternatives and rankings based on the degree of fuzzy membership. The result obtained was determined after measuring the closeness coefficient of alternatives and the values between them were very similar to each other. The researcher concluded then that the first rating is the highest value among the alternatives and is selected as the best alternative compared to other alternatives.

Furthermore, due to analysis of Fathi et al. (2011) on Fuzzy TOPSIS in workers selection for Padir Company in Iran shows that values are similar to each other between 0.4 to 0.6 as a result of the closeness coefficient of alternatives. The best alternatives and the first rating among other alternatives are considered to be the highest value of the closeness coefficient for alternatives. The two research studies above that have similar reasons for the best ranking are validated by this finding.
Çetinkaya et al (2016) studied on the refugee camps using Fuzzy TOPSIS for rating possible refugee camp locations. The model illustrates that the proposed alternate camp site is more fitting than the camp's current location. The result shows that the higher-ranking camp is closer to the water resource, slope and roadway proximity with a coefficient of closeness value of 0.6748,0.6747 and 0.6689, respectively. Too similar to each other is the value. The highest rating, therefore, has a closer proximity to water supplies.
Mavi et al (2016) analysed with Shannon Entropy and Fuzzy TOPSIS on supplier selection in the supply chain risk management context. The aim of their study was to pick suppliers in the supply chain's risk management sense. When assessing four suppliers, there were nine requirements considered. The supplier ranking was derived from the coefficient of closeness of the highest value.
Chu and Su (2012) studied on the selection of fixed seismic shelters in cities for evacuation using Fuzzy TOPSIS. In this study, they developed an assessment framework of 12 influential factor-related indices. Through the implementation of this process, a fixed seismic shelter for evacuation was chosen, confirming the applicability of this method.
Other than that, the studies by Ashrafzadeh et al (2012) demonstrated that Fuzzy TOPSIS has been successfully applied to the real warehouse place selection issue of a large company in Iran. The target was to produce a list of the best alternative aggregate scores. The highest score for the warehouse position was chosen as the best choice. In order to compare the value of the closeness coefficient of each alternative, Isfahan was proposed as the warehouse venue.
Behzadian's et al. (2012) claimed that the MCDM Technique for TOPSIS works satisfactorily through various fields of operation. This method has been successfully extended to a wide range of application areas and manufacturing sectors. The researchers used this strategy with a finite number of parameters to pick the best alternative.

Other Methods

Elsheikh et al. (2015) studied the flood risk analysis in Terengganu by using Spatial Multicriteria Evaluation technique, Analytical Hierarchy Process (AHP) and Ranking Method. The purpose of this research was to evaluate potential areas for floods. Annual rainfall, basin slope, drainage network, and soil type were the variables for flooding used in the study. As the result, AHP showed the percentage derived from the factors that could generate a map of areas of flood risk such as 38.7% for rainfall, 27.5% for drainage network, 19.8% for the slope of river basin and 14% for type of soil.
De Brito and Evers (2016) applied three techniques for flood risk management which were AHP, TOPSIS and Simple Additive Weighting (SAW). The ranking options for flood mitigation have been established, followed by danger, threat and vulnerability assessment. The decision-making process has helped to improve the consistency of decisions and to enforce the steps chosen.
Group decision making (GDM) combines the VIKOR method to quantify the spatial flood. In order to obtain spatial flood vulnerability of the southern Han River, the GDM approach

combined with the fuzzy VIKOR technique was compared. Using this approach, the result obtained will reduce the uncertainty in the techniques of data confidence and weight derivation. The focus of the next study will therefore be on the composition of factors for assessing flood vulnerability with regional capacity and features (Lee et al., 2015).

Methodology

A set of questionnaires was distributed among expert from Department of Irrigation and Drainage Kedah in order to rank flood factor (alternative) based on 6 zones: Zone 1 - Kota Setar , Kubang Pasu, and Pokok Sena; Zone 2 - Pendang, Kuala Muda dan Yan; Zone 3 - Padang Terap and Sik; Zone 4 – Baling; Zone 5 - Kulim and Bandar Baharu; and Zone 6 – Langkawi. There are 4 alternatives listed which are rainfall (A1), slope of basin (A2), type of soil (A3) and drainage system (A4) as shown in Figure 1.

The alternatives were obtained from a journal entitle Flood Risk Map Based on GIS and Multi Criteria Technique by Elsheikh et al. (2015).

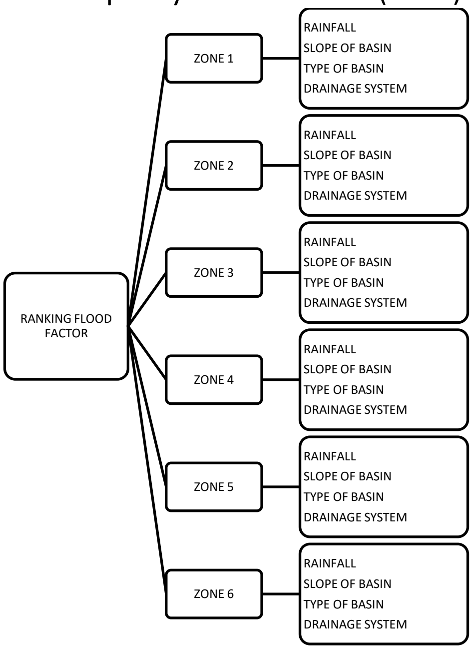

Figure 1. Hierarchy of ranking flood factor.

There are several steps of Fuzzy TOPSIS has been used in order to calculate, choose and rank the flood factor. According to Chen's Method (Jiang et al., 2009), there are several steps to be followed:

Step 1: Determine the weights for the criteria for evaluation

Convert the data to linguistic variable of fuzzy number. It is known as the weights of the different parameters and the qualitative ranking. In order to rate the parameters and alternatives, a 1 to 9 scale is typically used. Table 1 displays the fuzzy linguistic ranking for the TFN component as explained by the Sodhi and T.V. (2012). TFN can be defined as a triplet (1, m, u). Parameter 1 means the lowest value available. The m parameter shows the value that is most promising. While the u parameter shows the greatest possible value that a fuzzy event represents.

Table 1. Fuzzy Rating for Linguistic Variables

Fuzzy Number	Alternative Assessment	QA Weights
(1,1,3)	Very Poor (VP)	Very Low (VL)
(1,3,5)	Poor (P)	Low (L)
(3,5,7)	Fair (F)	Medium (M)
(5,7,9)	Good (G)	High (H)
(7,9,9)	Very Good (VG)	Very High (VH)

Step 2: The fuzzy decision matrix of the criteria was constructed using the linguistic variable and TFN from Step 1

$$\tilde{D} = \begin{pmatrix} \tilde{x}_{11} & \tilde{x}_{21} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \cdots & \cdots & \tilde{x}_{ij} & \cdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{pmatrix} \quad (1)$$

where i = 1, 2, …, m is referred to as alternatives while j = 1, 2, …, n is referred to as criteria and $\tilde{x}_{ij}$ is the aggregate fuzzy ratings given by $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$

where

$$a_{ij} = \min_k \{a_{ij}^k\},\ b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^k,\ c_{ij} = \max_k \{c_{ij}^k\} \quad (2)$$

The aggregate fuzzy weight of each criterion is calculated as below:

$$\tilde{w}_j^k = (w_{j1}, w_{j2}, w_{j3})$$

where

$$w_{ij} = \min_k \{w_{jk1}\},\ w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2},\ w_{j3} = \max_k \{w_{jk3}\} \quad (3)$$

Step 3: Normalize the matrix of the fuzzy decision

To calculate the normalized fuzzy decision matrix denoted by $\tilde{N}$, Eq. 4 is used.

$$\tilde{N} = [\tilde{n}_{ij}]_{mxn},\ i=1,2,\ldots.m;\ j=1, 2, \ldots n \quad (4)$$

where:

$$\tilde{n}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{ and } c_j^* = \max_i c_{ij} \quad (5)$$

$$\tilde{n}_{ij} = \left(\frac{a_j^-}{c_{ij}^a}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ and } a_j^- = \min_i a_{ij} \quad (6)$$

The score for normalized TFN that will be obtained was between 0 and 1. The weighted fuzzy normalized decision matrix $\tilde{V}$ then be calculated by multiplying the weights of evaluation criteria with the normalized fuzzy decision matrix $\tilde{n}_{ij}$ by the following Eq. 7.

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn},\ i=1,2,\ldots.m;\ j=1, 2, \ldots n \quad (7)$$

where

$$\tilde{V}_{ij} = \tilde{w}_{ij} \otimes \tilde{n}_{ij}$$

Step 4: Calculate FPIS and FNIS

The FPIS, A+ and FNIS, A- were calculated using Eq. 8 and Eq. 9. These steps are taken since the weighted normalized fuzzy decision matrix, the element $\tilde{V}_{ij}$ are normalized positive triangular fuzzy numbers and the range is closed interval [0,1].

$$A^{+}=\tilde{V}_1^{+},\tilde{V}_2^{+}, \ldots, \tilde{V}_N^{+} \quad (8)$$

$$A^{-}=\tilde{V}_1^{-},\tilde{V}_2^{-}, \ldots, \tilde{V}_N^{-} \quad (9)$$

where

$\tilde{v}_j^{+}=(1,1,1)$ and $\tilde{v}_j^{-}=(0,0,0)$

$i =1, 2, \ldots m; j = 1, 2, \ldots. n$

Step 5: Calculating the distance from FPIS and FNIS for each weighted alternative

The distance ($d_i^{+}$and d_i^{-}) of each weighted alternative from A+ and A- can be composed as the following formula:

$$d_i^{+} = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^{+}) \quad (10)$$

$i = 1, 2, \ldots m$

where

$$d(\tilde{v}_{ij}, \tilde{v}_j^{+}) = \sqrt{\frac{1}{3}\left[(\tilde{v}_{ij1} - \tilde{v}_{j1}^{+})^2 + (\tilde{v}_{ij2} - \tilde{v}_{j2}^{+})^2 + (\tilde{v}_{ij3} - \tilde{v}_{j3}^{+})^2\right]} \quad (11)$$

$$d_i^{-} = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^{-}) \quad (12)$$

$i = 1, 2, \ldots n$

where

$$d(\tilde{v}_{ij}, \tilde{v}_j^{-}) = \sqrt{\frac{1}{3}\left[(\tilde{v}_{ij1} - \tilde{v}_{j1}^{-})^2 + (\tilde{v}_{ij2} - \tilde{v}_{j2}^{-})^2 + (\tilde{v}_{ij3} - \tilde{v}_{j3}^{-})^2\right]} \quad (13)$$

Step 6: Closeness coefficient CC_i and the order of alternatives ranking

The ranking order of all alternatives can be determined according to closeness coefficient CC when the d_i^{+} to FPIS, A+ and d_i^{-} to FNIS, A- of each alternative been calculated. Each alternative's closeness coefficient is calculated as:

$$CC_i = \frac{d_i^{-}}{d_i^{-}+d_i^{+}} \quad ,i = 1, 2, \ldots. m \quad (14)$$

The most relevant element (alternative) indicates the alternative with the highest closeness coefficient.

Result and Discussion

A Table 2 presents the results for this study. The cumulative distance of those values to the ideal output values is indicated by FPIS and FNIS. The coefficient of closeness tests the flood factor 's efficiency effectiveness. The coefficient of closeness simultaneously represents the distance between FPIS and FNIS. The ranking for all flood factors was determined according to the closeness coefficient for all 12 districts in Kedah.

According to closeness coefficient, it shows that rainfall had the highest coefficient value. Therefore, rainfall is most important factor of flood occurrence in Kedah. The ranking order of the flood factors in Kedah districts are rainfall (CC1), drainage system (CC4), type of soil (CC3), and lastly slope of basin (CC2).

Table 2. Distance Measurement and Closeness Coefficient of the Factors.

Factor	FPIS	FNIS	Closeness coefficient (CC)	Rank
A_1 (rainfall)	7.0180	3.271	0.3180	1
A_2 (slope of basin)	7.0179	2.067	0.2270	4
A_3 (type of soil)	5.7000	2.000	0.2600	3
A_4 (drainage system)	6.0100	2.514	0.2951	2

Conclusions

This study has successfully achieved its objectives. It utilized Fuzzy TOPSIS to rank flood factors in Kedah. The highest rank is determined by the coefficient of closeness and closeness to FPIS at the highest value. The most important factor for flooding in Kedah is rainfall. By using Fuzzy TOPSIS, the value of closeness coefficient of rainfall is 0.318 which is the highest value compared to other factors. For future research, it will be interesting to rank both criteria and alternatives of flood factors simultaneously. This is because currently, Fuzzy TOPSIS can only rank the alternatives of flood factor. It will be interesting if flood factor is ranked together with the district that has the highest closeness coefficient.

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