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Path Selection using Fuzzy Weight Aggregated Sum Product Assessment

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Abstract

The search for safe evacuation routes is an important issue to save flood victims so they can reach the evacuation centre. This research is a simulation of searching for safe and fast travel evacuation route that have 24 alternative routes. Every road that will be transverse has a limit with certain criteria. Calculate of the weight of the constraints using the Multi-Criteria Decision Making (MCDM) method, namely the Analytical Hierarchy Process (AHP) and Weight Aggregated Sum Product Assessment (WASPAS) based on Fuzzy logic. The criteria of obstacle that qualitative for obscurity so that it makes sense fuzzy will provide supportive input for the MCDM problem. The Fuzzy AHP method is applied to calculate the weight of an application while the Fuzzy WASPAS (WASPAS-F)method is used to determine the safest alternative route. By using the Fuzzy AHP and WASPAS-F methods, a safe and fast pathway weights 0.662.
Keywords: evacuation route, MCDM, Fuzzy AHP, WASPAS-F.

1 Introduction

The occurrence of heavy rain in a specific area can cause flooding in the area. Losses due to floods reach 20% of injuries due to natural disasters. Flood disaster is an essential factor in hampering community development, sustainable economy, and human life [27, 55]. As a result of the high level of stagnant water due to rain, flood victims need to move to safer evacuation locations. To go to the evacuation area provided, the victims must choose a safe path. Several alternative roads are available for flood victims, but each alternative road that can be passed has obstacles. Obstacles faced by flood victims include high rainfall, high stagnant water, and others. The selection of a safe path and has the fastest travel time is done by a method that calculates the total weight of obstacles that exist in each path that can be crossed.

This paper presents a simulation of the selection of evacuation routes for flood victims. This route selection is a case example in making decisions in determining the best alternative from many alternatives based on several conflicting criteria [32, 55]. Decision making with a variety of criteria involves several stages, namely determining objectives, selecting criteria, determining alternatives, determining the weight of criteria, and applying the appropriate algorithm to determine alternative ranking [34]. Several multi-criteria decision making techniques have been used in various flood management cases [1] such as flood risk mapping [18, 25, 36], flood risk assessment [5, 16, 21, 42], zoning flood hazard [24, 38], flood vulnerability analysis [14, 22, 37], site selection for flood mitigation measures [2], and flood strategy priorities [15].

This paper is organized as follows. In part 2, the multi-criteria decision making is outlined, including AHP and WASPAS, fuzzy set theory, Fuzzy AHP, and WASPAS-F. The route search simulation based on Fuzzy AHP and WASPAS-F is introduced, and the process of determining research criteria is presented in section 3. Section 4 contains the calculation analysis. Finally, the conclusion is shown in the last section.

2 Literature review

Simulation of safe and fast route selection from several alternative routes is a case of decision making. In this research, the method used for route search simulation is the fuzzy AHP and WASPAS-F methods. Both methods are based on algorithms derived from fuzzy sets, fuzzy numbers, and Chang's extent analysis [13]. Chang's extent analysis introduced a new approach for handling fuzzy AHP, with the use of triangular fuzzy numbers for pairwise comparison scale of fuzzy AHP, and the use of the extent analysis method for the synthetic extent values of the pairwise comparisons.

2.1 Multi-Criteria Decision Making

The Multi-Criteria Decision Making (MCDM) method has been widely used in research. Based on different objectives and different types of data, MCDM problems can be classified into two main categories, namely Multiple-Attribute Decision Making (MADM) and Multiple-Objective Decision Making (MODM) [23, 51]. Approaches proposed by researchers include the Analytical Hierarchy Process (AHP) [40] and Technique For Order Reference by Similarity to Ideal Solution (TOPSIS) [3, 61]. Contemporary researchers integrate different MADM techniques to find the most effective solution [59, 60]. Turskis and Juodagalvienė integrated ten different MADM methods, including Game Theory, AHP, WASPAS, TOPSIS, EDAS, ARAS, Full Multiplicative form, Laplace Rule, Bayes Rule to one problem solution model [48]. Turskis et al. introduced a fuzzy multi-attribute performance measurement framework using the merits of both a novel Weighted Aggregated Sum-Product Assessment method with Fuzzy values (WASPAS-F) and Analytical Hierarchy Process (AHP) [50]. The AHP method was first introduced by Saaty [40] and has been applied in various cases including mapping of areas that are vulnerable to disasters [10, 26, 35, 41], power plant development [43], economics [33, 44], and construction management [20].

2.1.1 Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is a method used for assessment and decision making with various criteria and weight values. The AHP method is powerfull tool to elicitate weights of attributes. Turskis et al. using the AHP and ARAS-F methods to assess the construction site alternatives for the non-hazardous waste incineration plant [49]. This method uses a scale of 1 to 9 that represents the

Table 1: The scale of comparative assessment

Intensity of importance	Explanation
1	Two activities contribute equally to the objective
3	Experience and judgment slightly favour one activity over another
5	Experience and judgment strongly favour one activity over another
7	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	The value between two values of consideration that are close together

interests or one relative goal preference to another. Scale 1 represents the same interests between the two objectives. Scala 9 represents the extreme importance of one objective goal to another [7, 26, 40].

2.1.2 Weight Aggregated Sum Product Assessment

A MADM method, namely The Weighted Aggregated Sum-Product Assessment method (WASPAS), was introduced in 2012 by Zavadskas et al.[63]. The WASPAS method actually aggregates two approaches: the WSM (Weighted Sum Model) and the WPM (Weighted Product model). The Waspas method can be used to solve various problems from various environments. In [12], Chakraborty et al. use this method to solve five issues from a real-time manufacturing environment. The method was successfully applied for evaluating alternative technological or design solutions in construction [58], development of the wind park to power plant [4], and contractor selection [62]. The WASPAS method can also be used as a decision-making method in human risk assessment [8] and personnel selection for sales manager positions in the tourism sector [52]. Decision making on manufacturing process issues [11], and assessing residential homes that meet energy-efficient and human needs [57] can also be solved by this method.

The calculation process using WASPAS method are:

1. Make a decision matrix

$$X = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{pmatrix} \tag{1}$$

where m is the number of alternative candidates (m = *1, 2, . . . , m*) and n is the number of evaluation criteria and x_{11} is the alternative performance to i by taking into account the criteria to j.

2. Normalize the X matrix by calculating the:

Benefit criterion:

$$\bar{x_{ij}} = \frac{x_{ij}}{max_i x_{ij}} \tag{2}$$

Non-benefit criterion:

$$\bar{x_{ij}} = \frac{max_i x_{ij}}{x_{ij}} \tag{3}$$

3. Calculate the optimal WSM function value for each alternative based on:

$$Q_i = \sum_{j=1}^{n} \bar{x_{ij}} w_j \tag{4}$$

4. Calculate the optimal WPM function value for each alternative by:

$$P_i = \prod_{j=1}^{n} (\bar{x_{ij}})^{w_j} \tag{5}$$

5. Calculate the value of K_i using:

$$K_i = 0.5 \sum_{j=1}^{n} \bar{x_{ij}} w_j + 0.5 \prod_{j=1}^{n} (\bar{x_{ij}})^{w_j} \tag{6}$$

To improve the ranking accuracy and effectiveness of the decision-making process in the WASPAS method, a general equation used to determine the total importance of the second alternative is developed as the equation [12, 63]:

$$K_i = \lambda {Q_i}^{(1)} + (1-\lambda){P_i}^{(2)} = \lambda \sum_{j=1}^{n} \bar{x_{ij}} w_j + (1-\lambda) \prod_{j=1}^{n} (\bar{x_{ij}})^{w_j} \tag{7}$$

(λ=0, 0.1, ..., 1) where

$$\lambda = \frac{\sum_{i=1}^{m} P_i}{\sum_{i=1}^{m} Q_i + \sum_{i=1}^{m} P_i} \tag{8}$$

The WASPAS method is used to determine the interval for replacing equipment items from the optimal machine/service [19]. Maintenance in the manufacturing industry ensures the safety and reliability of the system and determines its productivity. The selection of garage locations in residential homes can also use the WASPAS-SVNS method [6]. The criteria used for making the right decision in choosing a garage location, the length of the foundation, internal functional communication, contextual, and aesthetic factors are chosen. The length of the foundation relates to the scope of earthworks and construction costs. Internal functional communication describes the comfort level of residential use, and user needs, the contexts associated with building zoning, aesthetics related to the beauty of the garage. The WASPAS and SWARA methods are used to select personnel for sales manager positions in the tourism sector. The Step-Wise Assessment Ratio Analysis (SWARA) method is used to select priorities based on environmental and economic situations by determining the weight of evaluation criteria. The WASPAS method is used to determine the order of candidates [52].

2.2 Fuzzy set theory

The fuzzy set theory was first introduced by Zadeh [56]. Fuzzy set theory is a fundamental approach for measuring the level of satisfaction and importance of vague and unclear linguistic variables on subjective human judgment [17]. The value of linguistic variables is qualitative. Uncertainty has the main characteristic that is grouping into a class that has a lack of clarity and the main characteristic of grouping into classes that have no clear boundaries. Triangular Fuzzy Number (TFN) represents an uncertain comparison assessment. TFN is a fuzzy number that is defined as a triplet (*l, m, u*).

A fuzzy number M on R becomes a triangular fuzzy number if the membership function is defined as [13].

$$\mu_M(x) = \begin{cases} \frac{x-l}{m-l} & , x \in [l, m] \\ \frac{x-u}{m-u} & , x \in [m, u] \\ 0 & , otherwise \end{cases} \tag{9}$$

where $l \leq m \leq u$, l is lower value, u is upper value and m is modal.

If there are two TFN, A = (l_1, m_1, u_1) and B = (l_2, m_2, u_2), the fundamental operation of TFN [13]:

$$(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{10}$$

$$(l_1, m_1, u_1) \ominus (l_2, m_2, u_2) = (l_1 - l_2, m_1 - m_2, u_1 - u_2) \tag{11}$$

$$(l_1, m_1, u_1) \odot (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2) \tag{12}$$

$$k \odot (l_1, m_1, u_1) = (kl_1, km_1, ku_1) \tag{13}$$

$$(l_1, m_1, u_1)^{-1} \approx (\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}) \tag{14}$$

Table 2: The scale of comparative assessment

Linguistic Variable	AHP Scale	Triangular Fuzzy Scale
Just equal	1	(1,1,1) if diagonal (1,1,3) the other
Moderately	3	(1,3,5)
Strongly	5	(3,5,7)
Very Strongly	7	(5,7,9)
Extremely	9	(7,9,9)

2.3 Fuzzy AHP

Fuzzy AHP is a decision-making method that combines the fuzzy and AHP method. The earliest work in fuzzy AHP appeared in van Laarhoven and Pedrycz [53], which compared fuzzy ratios described by triangular membership functions. In this method, judgment or decision-maker preferences are modeled using fuzzy logic. In addition to the fuzzy AHP method, researchers recently extended Eckenrode's rating technique with fuzzy values to determine the weights of attributes [46]. Fuzzy AHP is applied, for example, to the ranking and selection of alternatives in rice production practice [30], analytical procedures for managing an efficient green supply chain [29], and the selection of contractor's bidding [28].

The AHP pairwise comparison model uses a scale of 1 to 9. This AHP scale can be transformed into a triangular fuzzy scale, as in Table 2. This scale was introduced by Chang [13], Veerbathiran and Srinath [54] as a new approach to the use of triangular fuzzy numbers for the comparison scale of AHP fuzzy pairs.

Using the analytical development method on the Fuzzy AHP Chang, the following steps are applied [30, 45]:

If $X = x_1, x_2, \ldots, x_n$ is a set of object and $G = g_1, g_2, \ldots, g_n$ is the goal set. Then, the development of the analysis of each objective must be carried out. For each object M_{gi}^1 , $M_{gi}^2, \ldots,$ M_{gi}^m with $i = 1, 2, \ldots, n$ and $M_g i^j$ is a triangular fuzzy number and $j = 1, 2, \ldots, m$ then the value of development analysis m can be found.

Step 1: Value of synthetic extent for the ith object is calculated by

$$S_i = \sum_{j=1}^{m} M_{gi}^j \odot [\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j]^{-1} \tag{15}$$

where $[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j]^{-1}$ calculated using equation

$$\sum_{j=1}^{m} M_{gi}^j = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \tag{16}$$

$$[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j]^{-1} = (\frac{1}{\sum_{j=1}^{m} u_j}, \frac{1}{\sum_{j=1}^{m} m_j}, \frac{1}{\sum_{j=1}^{m} l_j}) \tag{17}$$

Step 2: calculate the degree of possibility $M_2(l_2, m_2, u_2) \geq M_1(l_1, m_1, u_1)$ by using :

$$V(\tilde{M}_2 \geq \tilde{M}_1) = \sup_{y \geq x} [min(\mu_{\tilde{M}_1}(x), \mu_{\tilde{M}_2}(x))] \tag{18}$$

where $\tilde{M}_1(l_1, m_1, u_1)$ and $\tilde{M}_2(l_2, m_2, u_2)$ are triangular fuzzy number. The slice between M_1 and M_2 can be seen in Fig.1.

equation (18) can be stated with the following equation :

$$V(\tilde{M}_2 \geq \tilde{M}_1) = \begin{cases} 1 & , if\ m_2 \geq m_1 \\ 0 & , if\ l_1 \geq u_2 \\ \frac{(l_1 - u_2)}{(m_2 - u_2) - (m_1 - l_1)} & , otherwise \end{cases} \tag{19}$$

Step 3: the degree of membership of each criterion is determined by

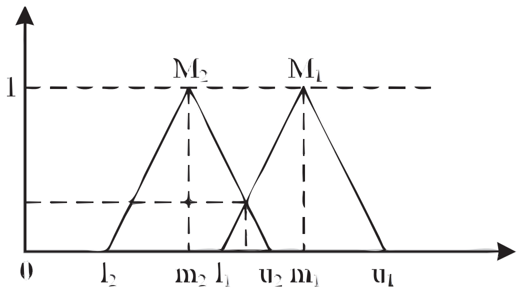

Figure 1: Slice between M_1andM_2 [45]

$$V(M \geq M_1,\ M_2,\ \ldots\ ,\ M_k) \quad = \quad V[(M \geq M_1)\ and\ (M \geq M_2)\ and\ \ldots\ and\ (M \geq M_k)]$$

$$= min\ V(M \geq M_1) \tag{20}$$

where $i = 1, 2,\ \ldots\ , k$.

Assume

$$d(A_i) = minV(S_i \geq S_k) \tag{21}$$

for $k = 1, 2, \ldots, n$; $k \neq$ i, the weight vector is calculated by the equation :

$$W^{'} = [d^{'}(A_1), d^{'}(A_2), \ldots, d^{'}(A_n)]^T \tag{22}$$

Step 4: normalized weight vectors can be calculated by

$$W = [d(A_1), d(A_2), \ldots, d(A_n)]^T \tag{23}$$

where weight W not a fuzzy number.

The Fuzzy AHP is used in the selection disaster logistics centre location proposed by Turğut et al. [45]. In this study, the Fuzzy AHP method is used to develop a decision support system with criteria. The questionnaire technique determines the weighting of the criteria used. The combination of AHP with fuzzy trapezium numbers is used to calculate the weight index of flood risk assessment and flood vulnerability [65]. Shannon's entropy theory, comprehensive fuzzy methods, and analytical hierarchy process show the weighting of modeling variables for landslide susceptibility evaluation [64]. The Fuzzy AHP is also used for the selection of shelter locations and evacuation planning for disaster victims [9].

2.4 Fuzzy WASPAS

Fuzzy WASPAS is a multi-criteria decision-making method in an uncertain environment [31, 39]. The advantage of using fuzzy in this method is to determine the relative importance of attributes that are not deterministic.

Turskis et al. introduced a fuzzy multi-attribute performance measurement framework using the merits of both a novel Weighted Aggregated Sum-Product Assessment method with Fuzzy values (WASPAS-F) and Analytical Hierarchy Process (AHP) [48]. Fuzzy WASPAS to control the shipping trolley in manufacturing. The fuzzy method used in this paper is related to the uncertainty of the estimated waiting time for the production line [39]. This production system consists of three parts, namely joint and independent Welding and Cleaning (WCL) and Assembly and maintenance (ATL). A trolley located between WCL and ATL transports the workpiece from one of the production lines (WCL) to the appropriate ATL. In [50], WASPAS-F is used to determine the most appropriate location to construct a shopping center building. The choice of shopping center location uses eight criteria, namely construction costs, economic value, access roads, competitors, characteristics of the population around the location, environmental impact, risks posed, and attractiveness of the shopping center.

Turskis et al. applied the model to solve the problem of ensuring the sustainable development of EU countries in terms of identifying critical information infrastructures [47].

A new approach to the WASPAS method that was developed based on the Interval-Valued Intuitionistic Fuzzy Sets (IVIFSs) is applied to the process of evaluating flood management control policies [31]. In this paper, a new formula is developed to determine the decision weight of experts based on the measurement of similarity. At the same time, Mishra et al. used the WASPAS fuzzy intuitionistic method to assess cellular phone service providers (TSP) [32].

3 Evacuation routes for flood victims

This section will discuss the resolution of problems related to simulating alternative route choices for flood victims. The proposed problem-solving flow chart is shown in Figure 2. The first step in making a safe and fast route selection simulation is done by modeling the environment. Road modeling and obstacle design are included in the environmental modeling design. Design obstacles on every road that might be crossed are:

1. The Slippery road. This criterion is designed to determine whether the road will be easy or not to be passed due to the presence of mud, soil, water, and/or rubbish that is scattered on the road surface.

2. The water that floods the road. The height of the water that floods the road is an obstacle that needs to be considered. The higher the water holding the road, the more difficult it will be for flood victims.

3. The river near the road. The existence and state of the river will affect the state of the surrounding water. The closer the road to the river, the more dangerous it will be for victims who will cross the road.

4. Existing drainage system. Removal of natural or artificial water masses will affect the height of standing water in certain areas, and the time it takes for the receding stagnant water. The better the drainage system, the faster the water will recede.

5. Vulnerability. Vulnerability is a set of conditions or conditions that determine whether a hazard situation that occurs will cause a disaster or not, so vulnerability will be one of the considerations for victims to go through the road.

Fuzzy Analytical Hierarchy Process (Fuzzy AHP) is used to calculate criteria weights. The second part is the Fuzzy Weighted Aggregated Sum-Product Assessment (WASPAS-F) method. The WASPAS-F method is used to determine the alternative order of routes that can be passed by flood victims. The flowchart of FAHP and WASPAS-F calculation can be seen in Figure 3.

Figure 4 shows several road routes that can be traversed by flood victims while walking from the disaster location to the evacuation site. Road routes can be defined with several roads that must be passed, among others:

- S - a - b - D
- S - c - b - D
- S - c - d - D
- S - e - d - D
- S - a - b - d - D
- S - a - c - b - D
- S - c - b - d - D
- S - c - d - g - D
- S - e - d - b - D
- S - e - d - g - D

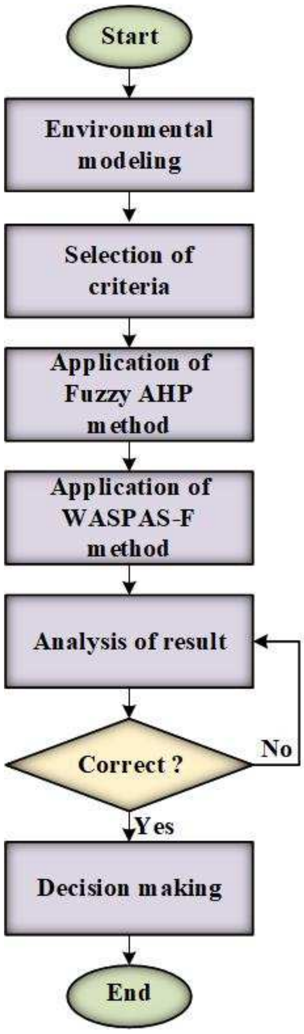

Figure 2: The flowchart of the proposed problem solving process

- S - e - f - g - D
- S - a - b - d - g - D
- S - a - b - c - d - D
- S - a - c - b - d - D
- S - c - b - d - g - D
- S - e - f - g - d - D
- S - a - b - c - d - g - D
- S - a - c - b - d - g - D
- S - c - d - e - f - g - D
- S - e - f - g - b - d - D
- S - a - b - d - e - f - g - D
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- S - a - b - c - d - e - f - g - D
- S - a - c - b - d - e - f - g - D

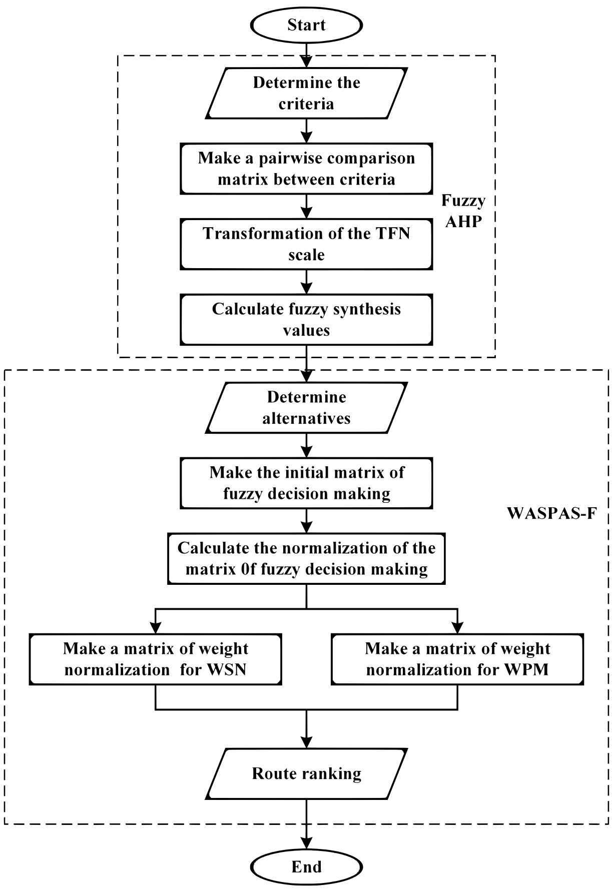

Figure 3: The flowchart of Fuzzy AHP and WASPAS-F calculation

Each obstacle is determined on the road, which obstructs the victim's path to the evacuation site. Each obstacle will be given weight. The determination of obstacle weights for each road is calculated using fuzzy logic.

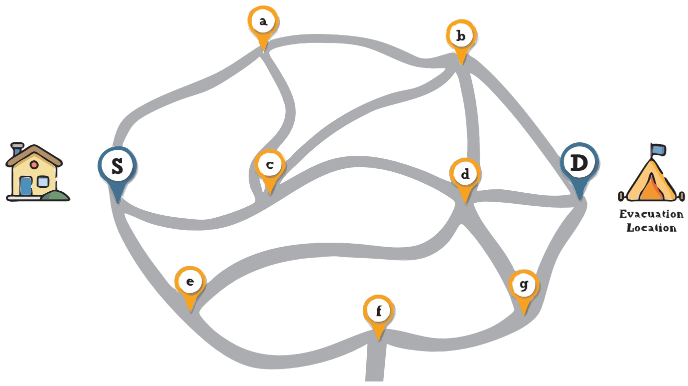

Figure 4: The model of routes that can be passed by flood victims

Table 3: Pair comparison between criteria

	C1	C2	C3	C4	C5
C1	(1,1,1)	(1/3,1,1)	(1/5,1/3,1)	(1,1,3)	(1/7,1/5,1/3)
C1	(1,1,1)	(1/3,1,1)	(1/5,1/3,1)	(1,1,3)	(1/7,1/5,1/3)
C1	(1,1,1)	(1/3,1,1)	(1/5,1/3,1)	(1,1,3)	(1/7,1/5,1/3)
C1	(1,1,1)	(1/3,1,1)	(1/5,1/3,1)	(1,1,3)	(1/7,1/5,1/3)
C1	(1,1,1)	(1/3,1,1)	(1/5,1/3,1)	(1,1,3)	(1/7,1/5,1/3)

3.1 Fuzzy AHP to search weight

3.1.1 Route search hierarchy structure

Figure 5 shows the hierarchical structure in the route search. The aim is to find a safe and fast route for flood victims who will go to the evacuation location. Victims can pass 24 alternative routes. In the selection of a route, five criteria need to be considered. These criteria are the level of road slippage (C1), the level of water inundated on the road (C2), the presence of a river located near the road (C3) and the drainage speed of the ditch (C4), and the level of vulnerability of flood victims that must be immediately considered to reach the evacuation location (C5). The five criteria are obstacles for each road the victim will pass.

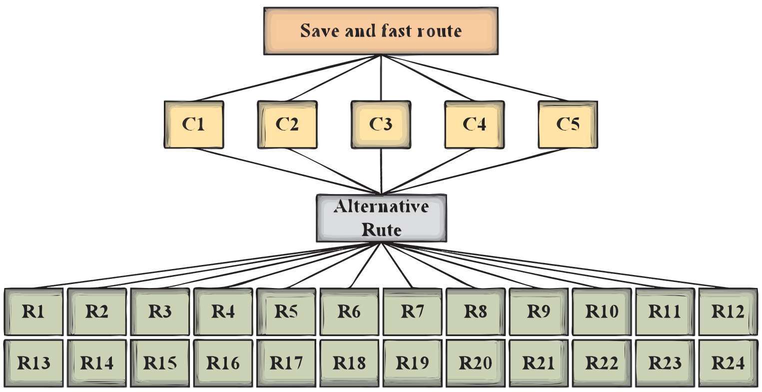

Figure 5: The route search hierarchy structure

3.1.2 Matrix of Importance Comparison between Criteria

Criteria comparison matrix is one of the most popular weighting methods in the Multi-Criteria Decision Making problem. A pairwise comparison matrix between criteria with a Triangular Fuzzy Number scale is fundamental in the Fuzzy AHP method. A pairwise comparison matrix between criteria for safe route search problems can be seen in table 3.

Table 4: Addition Triangular Fuzzy Number

	l	m	u
C1	2.767	3.533	6.333
C2	3.286	3.400	7.667
C3	6.200	12.333	19.000
C4	2.010	3.533	4.333
C5	11.000	10.000	27.000
sum	25.171	41.800	64.333

Table 5: Synthesis fuzzy criteria

	l	m	u
C1	0.042	0.085	0.252
C2	0.051	0.081	0.305
C3	0.096	0.295	0.755
C4	0.031	0.085	0.172
C5	0.171	0.455	1.073

3.1.3 Fuzzy Synthesis Value of Criteria

The next step is to determine the value of fuzzy synthesis (Si). Fuzzy synthesis values are used to get the relative weights for the criteria elements and can be calculated using Equation (15). The procedure for calculating the value of fuzzy synthesis is as follows :

- All elements of l in each criterion are added up. Likewise, all the elements m and u in each criterion. The results of adding l, m and u to each criterion can be seen in Table 4.

- After all the sums of l, m and u are obtained, each column in the fuzzy triangular number matrix is summed, as shown in the sum rows of Table 4.

- The next step is to divide each cell in the first column of Table 4, with the results of adding the first column number. This step is also carried out in the second and third columns of the sum matrix of fuzzy numbers in Table 4. The results of the calculations that have been made can be seen in Table 5.

3.1.4 Degree of membership in comparison of each criterion

To calculate the degree of membership of a comparison of fuzzy synthesis values to get the vector weights for the criteria used equation (11). The results of the calculation obtained the weight of the criteria vector :

$W'=[0.180, 0.264, 0.785, 0.003, 1]^T$

3.1.5 Normalization of vector weights

After the criteria vector weight is obtained, normalization of vector weight will be obtained, and the results will be :

W=[0.081, 0.118, 0.352, 0.001, 0.448]

3.2 Fuzzy WASPAS for ranking search

After obtaining the criteria weight vector value from the Fuzzy AHP method, then to evaluate alternative locations, the WASPAS-F method is used. From the weight of the vector of the criteria, we can draw the level of importance of the attribute.

3.2.1 Matrix of alternative fuzzy weighting

The first step in finding a safe and fast route to the WASPAS-F method is to assign a value to each alternative route (Route 1, Route 2, . . . , Route 24) for each predetermined criterion. Alternative routes have been determined based on the road modeling shown in Figure 3. Figure 3 shows 24 alternative routes that may be passed by flood victims. In this simulation, the obstacle for each path and the weight value is predetermined. The specified weight value is changed to Triangular Fuzzy

Table 6: The initial fuzzy decision making matrix for path selection

	Route 1			Route 2			Route 3			...	Route 24		
	α	β	γ	α	β	γ	α	β	γ	...	α	β	γ
C1	0.000	0.200	0.400	0.300	0.500	0.700	0.300	0.0500	0.700	...	0.300	0.500	0.700
C2	55	70	85	15	30	45	15	30	45	...	35	50	65
C3	120	160	200	60	100	140	60	100	140	...	60	100	140
C4	60	80	100	30	50	70	60	80	100	...	30	50	70
C5	6	10	14	6	10	14	6	10	14	...	6	10	14

Table 7: The normalized fuzzy decision making matrix for path selection

	Route 1			Route 2			Route 3			...	Route 24		
	α	β	γ	α	β	γ	α	β	γ	...	α	β	γ
C1	0.000	0.200	0.400	0.300	0.500	0.700	0.300	0.0500	0.700	...	0.300	0.500	0.700
C2	0.647	0.824	1.000	0.176	0.353	0.529	0.176	0.353	0.529	...	0.412	0.588	0.765
C3	0.600	0.800	3.333	0.600	0.714	2.333	0.600	0.714	2.333	...	0.300	0.500	0.700
C4	0.600	0.800	1.000	0.300	0.500	0.700	0.600	0.800	1.000	...	0.300	0.500	0.700
C5	0.429	0.714	1.000	0.429	0.714	1.000	0.429	0.714	1.000	...	0.429	0.714	1.000

Number (TFN). The value of obstacles for each criterion on each alternative route on a fuzzy scale can be seen in Table 6. α is the minimum value of TFN, β is modal value and γ is the maximum value of TFN.

3.2.2 Matrix of fuzzy weighting normalization

Table 7 shows the matrix that has been normalized using Equations (2).

3.2.3 Fuzzy normalization matrix for Weight Sum Model (WSM)

The fuzzy normalization weight matrix for Weighted Sum Model (WSM) is obtained by processing each matrix value using equations (4). The results of these calculations can be seen in Table 8.

3.2.4 Fuzzy normalization matrix for Weighted Product Model (WPM)

To get the fuzzy normalization matrix for the Weighted Product Model is obtained by processing Table 7 using the Equation (5). Table 9 shows the fuzzy normalization matrix for WPM.

3.2.5 The value of optimization function

Using Equations (7) and (8), the total weight of each route alternative can be calculated and can be seen in Table 10.

Table 8: The weight normalized matrix for WSM

Route	Q	Route	Q
1	0.990	13	0.859
2	0.831	14	0.859
3	0.831	15	0.831
4	0.831	16	0.831
5	0.859	17	0.858
6	0.834	18	0.858
7	0.831	19	0.858
8	0.694	20	0.834
9	0.979	21	0.886
10	0.831	22	0.882
11	0.858	23	0.886
12	0.858	24	0.667
$\sum Q$			20.335

Table 9: The weight normalized matrix for WPM

Route	P	Route	P
1	0.700	13	0.804
2	0.758	14	0.804
3	0.758	15	0.758
4	0.758	16	0.758
5	0.804	17	0.804
6	0.614	18	0.804
7	0.758	19	0.804
8	0.670	20	0.614
9	0.676	21	0.835
10	0.758	22	0.834
11	0.804	23	0.835
12	0.804	24	0.658
$\sum P$			18.179

Table 10: Integrated utility function value of WASPAS-F method

Route	K	Route	K
1	0.837	13	0.830
2	0.792	14	0.830
3	0.793	15	0.792
4	0.793	16	0.792
5	0.830	17	0.830
6	0.718	18	0.830
7	0.793	19	0.830
8	0.681	20	0.718
9	0.819	21	0.859
10	0.792	22	0.857
11	0.830	23	0.859
12	0.830	24	0.662

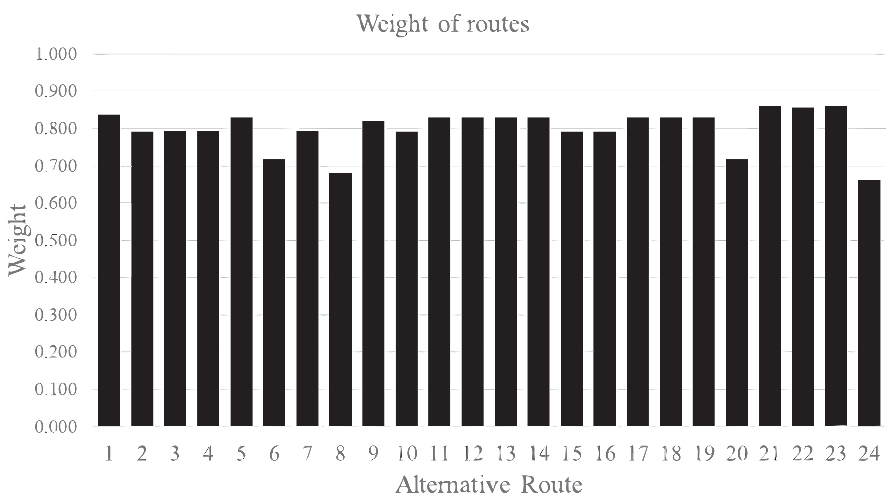

Figure 6: Weight of all routes

4 Analysis

Finding safe and fast paths for flood victims is an important problem when an area is rained and starts to flood. This simulation of path search is used as a learning model for safe route selection. With five types of obstacles (C1, C2, C3, C4, C5) determined, the consideration of road selection is still needed. From the predetermined values for each criterion, the Fuzzy AHP method obtained the weight of the criteria. Fuzzy AHP is a multi-criteria decision-making method that combines fuzzy methods and AHP methods. In this method, the preference is carried out by decision-makers on a numerical scale. The assigned numerical scale is transformed into a fuzzy scale. The final weight of the Fuzzy AHP method is not a fuzzy number. Fuzzy AHP is applied to identify the importance of criteria. The results of the weighted criteria obtained are w_{C1}= 0.081, w_{C2} = 0.118, w_{C3} = 0.352, w_{C4} = 0.001, $w_{C5}5$ = 0.448.

Criteria weights generated by the Fuzzy AHP method are used to process alternative obstacle weights in the WASPAS-F method. Similar to Fuzzy AHP, WASPAS-F is also a multi-criteria decision-making method in an uncertain environment. The WASPAS-F method stipulates alternative routes that may be passed by flood victims. On each alternative route, there is an obstacle. Obstacle weight values on alternative routes are specified in the TFN. The WASPAS-F method combines WSM and WPM. The WASPAS-F method is used to rank alternative routes.

Figure 6 shows the weight of each route calculated using the WASPAS-F method. The smallest weight is achieved by Route 24, with a value of 0.662. The highest weight is achieved by Route 23, which is 0.859. The route with the smallest weight indicates that the route is the safest and fastest route that can be passed by flood victims.

5 Conclusion

Rainy season with erratic rain levels, they are sometimes causing flooding in certain areas. If an area is flooded, the flood victims will be moved to a safe location. To reach the evacuation location needed a safe route that could be used by the victims. For this reason, a simulation is needed to obtain safe route choices for flood victims. This route search considers the dangers faced by flood victims when crossing the road. The smaller the threat faced by flood victims on a route, the route is safe for flood victims to pass.

This paper proposes the Fuzzy AHP and WASPAS-F methods to provide an alternative route that can be traversed for flood victims. The Fuzzy AHP method is a method that is simple, flexible, and able to handle quantitative and qualitative criteria better. The Fuzzy AHP method is used to find the weight of each route. The WASPAS-F method combines fuzzy, WSM, and WPM, which can improve the accuracy of the ranking of the proposed alternative routes given the uncertainty of preferences. From the calculations that have been done using the Fuzzy AHP and WASPAS-F methods show that the route that has the smallest obstacle is R24. R24 has the smallest weight, 0.662, so R24 is the safest route for flood victims.

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Author contributions

The authors contributed equally to this work.

Conflict of interest

The authors declare no conflict of interest.

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