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AHP Approach using Interval Neutrosophic Weighted Averaging (INWA) Operator for Ranking Flash Floods Contributing Factors

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Abstract: Aggregation operators are crucial in the process of multicriteria decision-making (MCDM) problems, as their main goal is to aggregate a collection of input to a single number. Analytic Hierarchy Process (AHP) has been used to solve a variety of MCDM situations in which crisp numbers are used to define linguistic assessment. The Interval-Valued Neutrosophic (IVN) number can consider the indeterminacy, fuzziness, and uncertainty in the real-world problem. A new combination of Interval Neutrosophic Weighted Averaging (INWA) aggregation operators into the AHP method is proposed in this study. The proposed combination method is applied to a case of factors affecting floods. In recent years, flood is one of the frequent natural disasters impacting Penang, one of the states that is famous for its tourism industry. Hence, an improved decision model is used to rank the factors of flash floods in Penang Malaysia. based on the INWA aggregated matrix implemented into the AHP approach is presented. The ranking order is determined after assessing the obtained data, with the highest score being the most important factor (rephrase ayat ni). Government and authorities can use the findings to establish early preparations and prevention strategies to deal with the flash floods problem.

Keywords: decision-making; fuzzy set theory; neutrosophic set theory; interval neutrosophic set theory; averaging operator

1. Introduction

Multi-criteria decision-making involves multiple decision makers and multiple deciding criteria. The issue is the use of a crisp number scale to describe the decision makers' opinions does not cater the fuzziness and indeterminacy during the evaluation process in real-world problems. To address flaws in real-number applications, fuzzy set theory was introduced by Lotfi Zadeh in 1965. A fuzzy set is a crisp set with a membership function that can take any value between 0 and 1. Several extensions of fuzzy set theories such as interval-valued fuzzy set, intuitionistic fuzzy set, neutrosophic set, and many more have been applied in various case studies. The neutrosophic set (NS) appears to be more reasonable and acceptable compared to these FSs [1]. Besides, the concept of neutrosophic sets introduced by Smarandache [2] is interesting and useful in modeling several real-life problems. The truth membership function, the indeterminacy membership function, and the falsity membership function, all of which are entirely independent, are related to the neutrosophic set theory (NS), which is a generalization of the intuitionistic fuzzy set (IFS) theory. This form clearly and successfully deals with not only missing information but also indeterminate and inconsistent information [3]. Hence, neutrosophic sets (NS) can help in dealing with the uncertainty that exists in real-world circumstances.

Wang et al. [4] established the concept of Interval-Valued Neutrosophic Sets theory (IVNS), which is a subset of neutrosophic sets [5]. This concept is characterized by a membership function, a non-membership function, and an indeterminacy function, whose values are intervals rather than real numbers. IVNS is considered a valuable and practical tool for dealing with indeterminate and inconsistent information in the real world since it is more powerful than NS in dealing with vagueness and uncertainty. In multi-criteria decision-making problems, multiple decision-makers must be aggregated using the appropriate aggregation operators.

Aggregation operators are an interesting area of research that plays an important role in group decision-making analysis. The traditional aggregation operators are usually based on the arithmetic and geometric mean approaches, often known as algebraic sum and algebraic product. The issue is the averaging method assumes a similar weight for all decision makers. In the real world, different weights may be assigned to different evaluations by multiple decision-makers [6]. Hence, Aczel and Saaty [7] proposed a weighted geometric (WG) mean aggregation operator for the synthesis of ratio judgments in the AHP method while Dong and Dong [8] later proposed a weighted arithmetic (WA) aggregation operator with a fuzzy set as its quantifier. In the neutrosophic environment, several neutrosophic aggregation operators were suggested, such as Interval Neutrosophic Weighted Averaging (INWA) and Interval Neutrosophic Weighted Geometric (INWG) [9]. In this study, the implementation of the INWA aggregation operator into the Multi-Criteria Decision-Making (MCDM) method is introduced.

Decision-making is a process of selecting the best alternatives based on certain criteria. MCDM also known as Multi-Criteria Decision Analysis (MCDA) is a method or process of decision-making involving multiple criteria that need to be considered to choose the best option between them. This method has been used in many fields such as engineering [10], management science [11], education [12], investment problem [13], and medical science [14]. There are many methods available to solve MCDM problems such as the Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarities to Ideal Solution (TOPSIS) [15,16], Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) [17], and Decision-Making Trial and Evaluation Laboratory (DEMATEL) [18]. Amongst these MCDM methods, AHP is a more flexible and realistic method to use because it produces a simple way to find the relationships between criteria and alternatives [19]. The AHP method was proposed by Saaty [20] as an easily justified, discriminating, and intentional MCDM technique. AHP has the ability to detangle a difficult problem by breaking it down into smaller parts with the hierarchical structure approach. Recently, most of the AHP methods have been extended based on fuzzy set and neutrosophic set theories. The application of the AHP method also has been diversified. In this study, the proposed AHP method with INWA operator is used to solve the flash floods problem in Penang.

Flash floods are the most terrifying natural disasters that can occur with little or no warning. A flash flood is a rapid-developing, short-duration flood that occurs within a few hours of the triggering event. Perhaps, flash floods are the most frequent disasters that happened and caused the greatest damage to the world. Flash floods occurred because of natural factors and human factors. Based on the literature review, eight factors are taken into consideration, which are rain intensity, rain duration, poor drainage system, dam and levee failure, urbanization, slow-moving thunderstorm, soil erosion, and land use pattern [21-29]. Five decision makers are invited to answer the questionnaire by pairwise comparison between factors. The findings of this study will be beneficial to the Drainage Irrigation Department (DID) or even the society as a source of reference that can be used to identify the most important factor in flash floods occurs. Hence, this research is important to help the Drainage Irrigation Department (DID), the in-charge agency of natural disasters in Penang, and the society recognized the most important factors that caused flash floods happened more accurately so that they are better prepared to deal with flash floods in the future. Section 2 goes over some preliminary concepts. Section 3 describes details the AHP's research methodology with the INWA operator. Section 4 discusses the proposed method's application to the problem of flash floods, and Section 5 concludes with remarks.

2. Preliminaries

In this section, we review some basic concepts related to INVS which will be used in the rest of the paper.

Definition 1: [4] Interval-Valued Neutrosophic (IVN) Sets

Let X be a universe of discourse and Int [0,1] be the set of all closed subsets of [0,1]. Then an interval neutrosophic set is defined as:

$$A=\left\{\left\langle x,u_A(x),p_A(x),v_A(x)\right\rangle : x\in X\right\} \quad (1)$$

where $u_A : X \to Int\left[0,1\right], p_A : X \to Int\left[0,1\right]$ and $v_A : X \to Int\left[0,1\right]$ with $0\le \sup u_A^U(x)+\sup p_A^U+\sup v_A^U \le 3$ for all. The interval $u_A(x), p_A(x)$ and $v_A(x)$ denote the truth-membership degree, the indeterminacy-membership degree and the falsity-membership of x to A respectively.

For convenience, if let $u_A(x)=\left[u_A^L(x),u_A^U(x)\right], p_A(x)=\left[p_A^L(x),p_A^U(x)\right]$, and $v_A(x)=\left[v_A^L(x),v_A^U(x)\right]$,then $A=\left\{x,\left[u_A^L(x),u_A^U(x)\right],\left[p_A^L(x),p_A^U(x)\right],\left[v_A^L(x),v_A^U(x)\right]: x\in X\right\}$

with the condition, $0 \le \sup u_A^U(x) + \sup p_A^U + \sup v_A^U \le 3$ for all $x \in X$. Here, we only consider the sub-unitary interval of [0,1]. Therefore, an interval neutrosophic set is clearly a neutrosophic set [3]. Table 1 shows the IVN scales.

Table 1: Linguistic IVN Scales [3]

Linguistic Variables	**IVN**
Equal Importance (EI)	<[0.5,0.5],[0.5,0.5],[0.5,0.5]>
Equal Importance Complement (EI^C)	<[0.5,0.5],[0.5,0.5],[0.5,0.5]>
Weakly More Importance (WMI)	<[0.5,0.6],[0.35,0.45],[0.4,0.5]>
Weakly More Importance Complement (WMI^C)	<[0.4,0.5],[0.35,0.45],[0.5,0.6]>
Moderate Importance (MI)	<[0.55,0.65],[0.3,0.4],[0.35,0.45]>
Moderate Importance Complement (MI^C)	<[0.35,0.45],[0.3,0.4],[0.55,0.65]>
Moderately More Importance (MMI)	<[0.6,0.7],[0.25,0.35],[0.3,0.4]>
Moderately More Importance Complement (MMI^C)	<[0.3,0.4],[0.25,0.35],[0.6,0.7]>
Strong Importance (SI)	<[0.65,0.75],[0.2,0.3],[0.25,0.35]>
Strong Importance Complement (SI^C)	<[0.25,0.35],[0.2,0.3],[0.65,0.75]>
Strongly More Importance (SMI)	<[0.7,0.8],[0.15,0.25],[0.2,0.3]>
Strongly More Importance Complement (SMI^C)	<[0.2,0.3],[0.15,0.25],[0.7,0.8]>
Very Strong Importance (VSI)	<[0.75,0.85],[0.1,0.2],[0.15,0.25]>
Very Strong Importance Complement (VSI^C)	<[0.15,0.25],[0.1,0.2],[0.75,0.85]>
Very Strongly More Importance (VSMI)	<[0.8,0.9],[0.05,0.1],[0.1,0.2]>
Very Strongly More Importance Complement ($VSMI^C$)	<[0.1,0.2],[0.05,0.1],[0.8,0.9]>
Extreme Importance (EI)	<[0.9,0.95],[0,0.05],[0.05,0.15]>
Extreme Importance Complement (EI^C)	<[0.05,0.1],[0,0.05],[0.85,0.95]>
Extremely High Importance (EHI)	<[0.95,1],[0,0],[0,0.1]>
Extremely High Importance Complement (EHI^C)	<[0,0.05],[0,0],[0.9,1]>
Absolutely More Importance (AMI)	<[1,1],[0,0],[0,0]>
Absolutely More Importance Complement (AMI^C)	<[0,0],[0,0],[1,1]>

Definition 2: [30] Interval Neutrosophic Weighted Average (INWA) Operator

Let $A = \{A_1, A_2, ..., A_n\}$ be a collection of Interval Neutrosophic Set (INS), where $A_j = \langle [T_j^L, T_j^U], [I_j^L, I_j^U], [F_j^L, F_j^U] \rangle$ $(j = 1, 2, ..., n)$ in interval neutrosophic number and if

$INWA_W\left\{A_1, A_2, ..., A_n\right\} = (w_1 A_1 \oplus w_2 A_2 \oplus ... \oplus w_n A_n)$, then INWA is called an interval neutrosophic weighted averaging (INWA) operator of dimension *n*, where $w = \left(w_1, w_2, ..., w_n\right)^T$ is the weight vector of $A_j\,(j = 1, 2, ..., n)$, weight $w_j \in \left[0,1\right]$ and $\sum_{j=1}^{n} w_j = 1$.

3. Methodology

3.1 Research Framework

The research framework of this study presents the workflow to determine the most important factor of flash floods as shown in Figure 1.

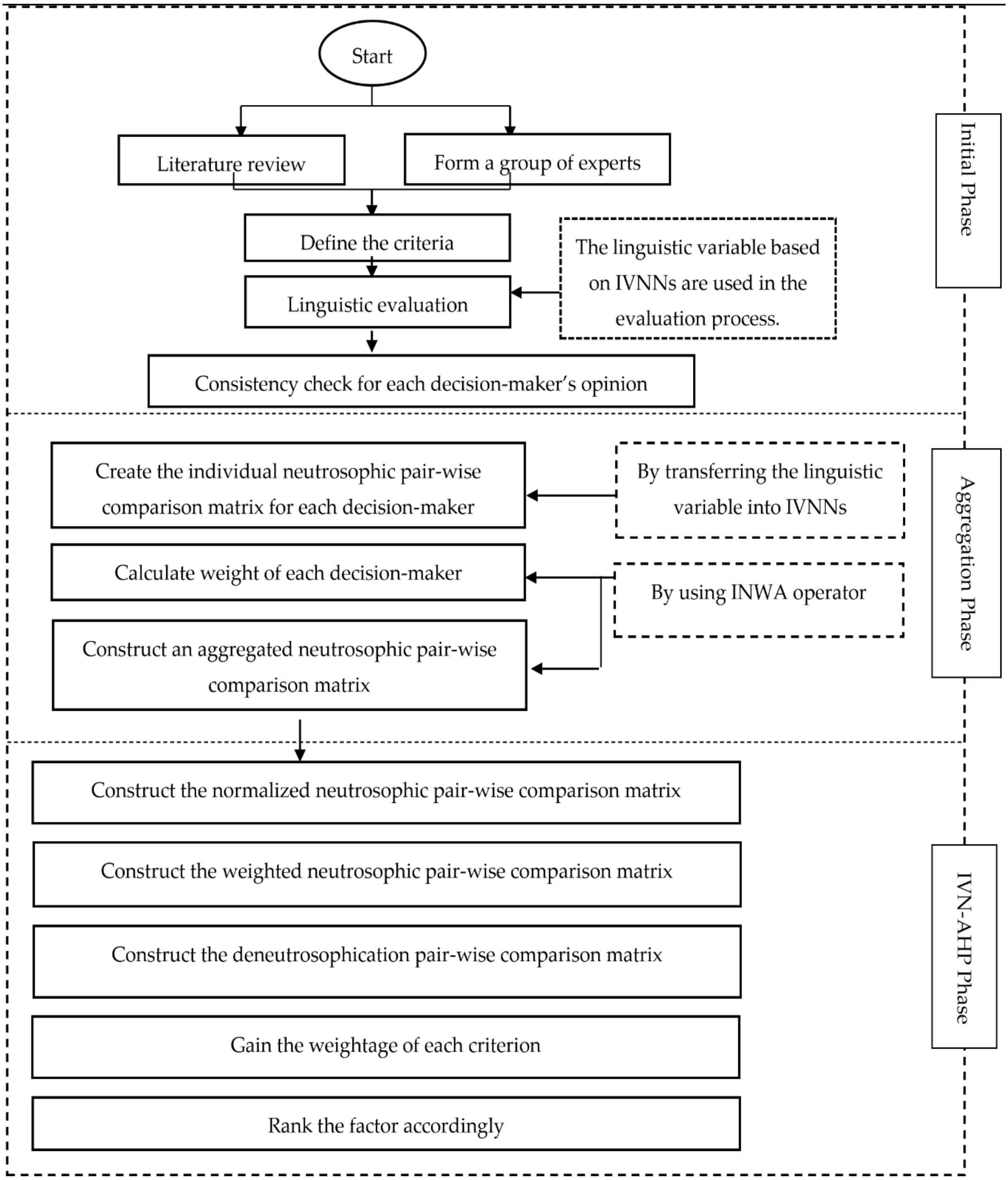

Figure 1: Research Framework

3.2 Phase 1: Data Collection

Data collection is the systematic process of acquiring and measuring information on variables of interest in order to answer research questions, test hypotheses, and evaluate outcomes. A survey was conducted to analyse the factor of flash floods that occurred in Penang. The questionnaires were given to five decision-makers at the Department of Irrigation and Drainage Seberang Perai Utara Pulau Pinang, who are experts in determining which factor is the most important. The decision-makers are required to give opinions on the evaluation of pair-wise comparison for factors. The data obtained is called primary data. The questionnaires contained two sections which are Section A and Section B.

Section A is about demographic profiles such as gender, position, and years of working experience while in Section B, decision-makers have to evaluate the pair-wise comparison between all the factors by using the linguistic scale. The decision makers' pair-wise comparisons are converted into the Interval-Valued Neutrosophic scale as in Step 3.2.

3.3 Phase 2: Data Evaluation – IVN-AHP Method

The AHP method is based on the logic of structuring a problem in hierarchies and then evaluating the components in the hierarchy through pairwise comparisons. Although AHP is a popular solution for MCDM problems, it does not always reflect human thought. Unlike traditional AHP, IVN-AHP can effectively integrate human cognition into decision-making by expressing uncertainty using three variables (*T, I, and F*). The weights of the factors affecting flash floods are calculated in this study using the IVN-AHP methodology. The steps of IVN-AHP are given below [3]:

Step 1: Identify the factors of the decision-making problem based on the literature.

Step 2: Decompose the complex problem into a hierarchical structure.

Step 3: Employs pair-wise comparison of the factors using a linguistic scale.

Step 3.1: Transform to crisp scale and calculate the Consistency Ratio.

i) Develop a pair-wise comparison matrix based on the decision-maker preference using a crisp number for each factor.

$$S_{ij} = \begin{matrix} C_1 \\ \vdots \\ C_n \end{matrix} \begin{pmatrix} 1 & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ 1/S_{1n} & \cdots & 1 \end{pmatrix} \quad (2)$$

ii) The resulting weights were estimated using Row Geometric Mean Method (RGMM) as proposed by Saaty (1980).

$$C_j = \left[\prod_{j=1}^{i} C_{ij} \right]^{\frac{1}{i}} \quad (3)$$

iii) Calculate the weight of each criterion

$$w_j = \frac{\left[\prod_{j=1}^{i} S_{ij} \right]^{\frac{1}{i}}}{\sum_{j=1}^{i} \left[\prod_{j=1}^{i} S_{ij} \right]^{\frac{1}{i}}} \quad (4)$$

iv) Find the eigenvector and using the equation as follows:

$$Sw = S \times w \quad (5)$$

$$\lambda_{\max} = \frac{Sw}{n \times w} \quad (6)$$

where,

S : comparison matrix,
w : eigenvector of the matrix S,
n : number of criteria,
$\lambda_{\max}$: largest eigenvalue.

v) Calculate the consistency index (CI)

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{7}$$

iv) To calculate the consistency ratio ($CR \leq 0.1$), divide the consistency index (CI) with random index (RI). We assume that the data obtained is consistent if CR for crisp number consistent. The random index (RI) value is selected based on the sample size of n matrix as shown in Table 2.

$$CR = \frac{CI}{RI} \tag{8}$$

Table 2: Random Inconsistency Index (RI) for n = 1,2,...,12 [20]

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

Step 3.2: Transform the pair-wise comparison based on linguistic scale to Interval Valued Neutrosophic Set scale introduced by Wang et al. [4] and evaluate the pair-wise comparison of the factors.

Step 4: Aggregation Process

In this phase, to aggregate all decision-makers' opinions, the INWA operator is employed to get the weight of decision-maker.

Step 4.1: Weight of Decision Maker

i. Develop a pair-wise comparison matrix based on the decision-maker position using an Interval-Valued Neutrosophic (IVN) Set.

ii.

$$P = \begin{matrix} DM_1 \\ DM_2 \\ \vdots \\ DM_n \end{matrix} \begin{bmatrix} [T_{11}^L, T_{11}^U], & [I_{11}^L, I_{11}^U], & [F_{11}^L, F_{11}^U] & \cdots & [T_{1n}^L, T_{1n}^U], & [I_{1n}^L, I_{1n}^U], & [F_{1n}^L, F_{1n}^U] \\ [T_{21}^L, T_{21}^U], & [I_{21}^L, I_{21}^U], & [F_{21}^L, F_{21}^U] & \ddots & & \vdots & \\ & \vdots & & \ddots & & \vdots & \\ [T_{n1}^L, T_{n1}^U], & [I_{n1}^L, I_{n1}^U], & [F_{n1}^L, F_{n1}^U] & \cdots & [T_{nn}^L, T_{nn}^U], & [I_{nn}^L, I_{nn}^U], & [F_{nn}^L, F_{nn}^U] \end{bmatrix} \tag{9}$$

ii. Converting the neutrosophic reference relations into their corresponding crisp preference relations by deneutrosophicated method.

$$D(x)=\left(\frac{T_{kj}^{L}(x)+T_{kj}^{U}(x)}{2}+I_{kj}^{U}(x)\left(1-\frac{I_{kj}^{L}(x)+I_{kj}^{U}(x)}{2}\right)-\left(1-F_{kj}^{U}(x)\right)\left(\frac{F_{kj}^{L}(x)+F_{kj}^{U}(x)}{2}\right)\right) \quad (10)$$

iii. Calculate the weight of matrix P by aggregating using the Row Geometric Mean Method (RGMM).

$$DM_{j}=\left[\prod_{j=1}^{i} DM_{ij}\right]^{\frac{1}{i}} \quad (11)$$

iv. Calculate the weight of each decision maker.

$$w_{j}=\frac{\left[\prod_{j=1}^{i} P_{ij}\right]^{\frac{1}{i}}}{\sum_{j=1}^{i}\left[\prod_{j=1}^{i} P_{ij}\right]^{\frac{1}{i}}} \quad (12)$$

Step 4.2: Aggregate with the pair-wise comparison obtained in Step 3.2 using INWA operator.

$$INWA_{w}\left\{A_{1},A_{2},\dots,A_{n}\right\}=\left\langle\begin{array}{l}\left[1-\prod_{j=1}^{n}(1-T_{j}^{L}(x))^{w_j},1-\prod_{j=1}^{n}(1-T_{j}^{U}(x))^{w_j}\right],\\ \left[\prod_{j=1}^{n}(I_{j}^{L}(x))^{w_j},\prod_{j=1}^{n}(I_{j}^{U}(x))^{w_j}\right],\\ \left[\prod_{j=1}^{n}(F_{j}^{L}(x))^{w_j},\prod_{j=1}^{n}(F_{j}^{U}(x))^{w_j}\right]\end{array}\right\rangle \quad (13)$$

Step 5: Ranking Process

In this phase, the weight obtained will be used to rank the factor of flash floods. Then, the highest the weight will be the most critical factor.

Step 5.1: The constructed pair-wise comparison obtained from the aggregated using INWA is used.

Step 5.2: The importance weights, $\bar{N}_{ij}$ of the factors are normalized to make them comparable data and thus to rate and rank factors.

$$N_{ij}=\left[\frac{T_{kj}^{L}}{\sum_{k=1}^{n}T_{kj}^{U}},\frac{T_{kj}^{U}}{\sum_{k=1}^{n}T_{kj}^{U}}\right],\left[\frac{I_{kj}^{L}}{\sum_{k=1}^{n}I_{kj}^{U}},\frac{I_{kj}^{U}}{\sum_{k=1}^{n}I_{kj}^{U}}\right],\left[\frac{F_{kj}^{L}}{\sum_{k=1}^{n}F_{kj}^{U}},\frac{F_{kj}^{U}}{\sum_{k=1}^{n}F_{kj}^{U}}\right];\ j=1,2,\dots,n \quad (14)$$

Step 5.3: The arithmetic mean of each row is calculated to obtain the neutrosophic importance weight, W_j vector of the factors by Equation (15).

$$W_j = \left[\frac{\sum_{k=1}^{n} \frac{T_{1j}^L}{\sum_{k=1}^{n} T_{kj}^U}}{n}, \frac{\sum_{k=1}^{n} \frac{T_{1j}^U}{\sum_{k=1}^{n} T_{kj}^U}}{n} \right], \left[\frac{\sum_{k=1}^{n} \frac{I_{1j}^L}{\sum_{k=1}^{n} I_{kj}^U}}{n}, \frac{\sum_{k=1}^{n} \frac{I_{1j}^U}{\sum_{k=1}^{n} I_{kj}^U}}{n} \right], \left[\frac{\sum_{k=1}^{n} \frac{F_{1j}^L}{\sum_{k=1}^{n} F_{kj}^U}}{n}, \frac{\sum_{k=1}^{n} \frac{F_{1j}^U}{\sum_{k=1}^{n} F_{kj}^U}}{n} \right] \quad (15)$$

Step 5.4: All the above steps are repeated for each factor.

Step 5.5: In order to obtain the crisp weights of the factors, the deneutrosophication formula in Equation (10) is used. **Step 5.6**: Rank the weight accordingly.

3.4 Phase 3: Comparison Analysis

The aggregation operator changes to INWG operator as Equation (16) follows then Step 5.1 until Step 5.6 repeated:

$$INWG_w\left\{A_1, A_2, ..., A_n\right\} = \left\langle \begin{array}{l} \left[\prod_{j=1}^{n} (T_j^L(x))^{w_j}, \prod_{j=1}^{n} (T_j^U(x))^{w_j} \right], \\ \left[1 - \prod_{j=1}^{n} (1 - I_j^L(x))^{w_j}, 1 - \prod_{j=1}^{n} (1 - I_j^U(x))^{w_j} \right], \\ \left[1 - \prod_{j=1}^{n} (1 - F_j^L(x))^{w_j}, 1 - \prod_{j=1}^{n} (1 - F_j^U(x))^{w_j} \right] \end{array} \right\rangle \quad (16)$$

Then compare the weight of each factor and the ranking based on different aggregation operator.

4. Application

4.1 Weight of decision-maker

The weight of the decision-maker is important in aggregating the pairwise comparison based on decision makers' opinions. In this study, the weight of decision-makers is calculated by using AHP method in interval neutrosophic environment. During the comparison phase, the decision-makers' weight is compared based on their positions. The decision-maker with higher position has more experience in handling the flash floods. Table 3 shows the comparison between the position of each decision maker in linguistic term.

Table 3: Pair-wise Judgement for Decision Makers' Weight in Linguistic Term

Decision Maker	DM1	DM2	DM3	DM4	DM5

DM1	EI	MI	SI	VSI	EHI
DM2	MI^C	EI	MI	SI	VSI
DM3	SI^C	MI^C	EI	MI	SI
DM4	VSI^C	SI^C	MI^C	EI	MI
DM5	EHI^C	VSI^C	SI^C	MI^C	EI

Then, the pair-wise comparison in linguistic term is converted into interval neutrosophic numbers by the conversion scale of IVNs (refer Table 1). Then, the pair-wise judgement of decision-makers' weight is calculated by using deneutrosophication formula to obtain crisp pair-wise comparison. Table 4 shows the result after deneutrosophication formula applied. The example of calculation for DM1 as follows:

$$D(DM1)_{DM1}=\left(\left(\frac{0.5+0.5}{2}\right)+0.5\left(\frac{0.5+0.5}{2}\right)-(1-0.5)\left(\frac{0.5+0.5}{2}\right)\right)=0.5$$

Table 4 Result of Deneutrosophication Calculation

Decision Maker	DM 1	DM 2	DM 3	DM 4	DM 5
DM 1	0.5	0.64	0.73	0.82	0.93
DM 2	0.45	0.5	0.64	0.73	0.82
DM 3	0.35	0.45	0.5	0.64	0.73
DM 4	0.25	0.35	0.45	0.5	0.64
DM 5	0.03	0.25	0.35	0.45	0.50

Then, Row Geometric Mean (RGM) formula is used to calculate weight vector as shown in Table 5. The example of calculation for row 1 as follows:

$$DM1=\left(0.5\times0.64\times0.73\times0.82\times0.93\right)^{\frac{1}{5}}=0.71$$

Table 5: Result of Weight Vector

Decision Maker	Weight Vector
DM 1	0.71
DM 2	0.61
DM 3	0.52
DM 4	0.42
DM 5	0.22
Total	2.47

Finally, the weight of each decision makers obtained as shown in Table 6. The example calculation as shown below:

$$W_{DM1} = \frac{0.71}{2.47} = 0.29$$

Table 6: Weight of each DM

Position	Decision Maker	Weight, *W*
District engineer	DM 1	0.29
Senior assistant engineer	DM 2	0.25
Assistant engineer	DM 3	0.21
Administrative engineer	DM 4	0.17
Officer	DM 5	0.09
	Total	1.00

4.2. Implementation of IVN-AHP based on INWA Operator

The decision makers' opinion gathered in pair-wise comparison. Then, the consistency ratio was check for each decision-makers' opinion and all decision-makers' opinions are consistent since the consistency ratio for each decision-maker's opinion is less than 0.10. For example, Table 7 shows the pair-wise comparison based on DM's 1 opinion in linguistic term.

Table 7: Pair-wise Comparison based on DM's 1 Opinion in Linguistic Term.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	EI	SI	EI	WI	SI^C	EI	MP	MI
C2	SI^C	EI	WI^C	EI	MI^C	MI^C	WI	WI
C3	EI	WI	EI	MI	EI	EI	SI	WI
C4	WI^C	EI	MI^C	EI	MI^C	MI^C	WI	WI^C
C5	SI	MI	EI	MI	EI	EI	MI	WI
C6	EI	MI	EI	MI	EI	EI	VSI	SI
C7	MP^C	WI^C	SI^C	WI^C	MI^C	VSI^C	EI	SI^C
C8	MI^C	WI^C	WI^C	WI	WI^C	SI^C	SI	EI

Table 7 shows example of pair-wise comparison based on opinion from decision maker 1 in term of interval neutrosophic scale. Then, all the five decision makers' opinion is aggregated using INWA operator and the results are shown in Table 8. The following calculation is demonstrated for cell C11 by using INWA aggregation operator:

$$INWA_W\{DM_1,DM_2,DM_3,DM_4,DM_5\}=\begin{bmatrix} 1-\left((1-0.5)^{0.29}\times(1-0.5)^{0.25}\times(1-0.5)^{0.21}\times(1-0.5)^{0.17}\times(1-0.5)^{0.09}\right), \\ 1-\left((1-0.5)^{0.29}\times(1-0.5)^{0.25}\times(1-0.5)^{0.21}\times(1-0.5)^{0.17}\times(1-0.5)^{0.09}\right) \\ 0.5^{0.29}\times0.5^{0.25}\times0.5^{0.21}\times0.5^{0.17}\times0.5^{0.09}, 0.5^{0.29}\times0.5^{0.25}\times0.5^{0.21}\times0.5^{0.17}\times0.5^{0.09} \\ 0.5^{0.29}\times0.5^{0.25}\times0.5^{0.21}\times0.5^{0.17}\times0.5^{0.09}, 0.5^{0.29}\times0.5^{0.25}\times0.5^{0.21}\times0.5^{0.17}\times0.5^{0.09} \end{bmatrix}$$

$$INWA_W\{DM_1,DM_2,DM_3,DM_4,DM_5\}=[0.5,0.5,0.5,0.5,0.5,0.5]$$

Table 8: INWA Aggregated Matrix

	C1						C2					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.6633	0.7552	0.1932	0.2921	0.2448	0.3367
C2	0.2889	0.3571	0.1932	0.2921	0.6429	0.7111	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
C3	0.5129	0.5423	0.4406	0.4731	0.4577	0.4871	0.6311	0.7292	0.2117	0.3006	0.2708	0.3689
C4	0.2886	0.3894	0.2209	0.3251	0.6106	0.7114	0.4664	0.4881	0.4406	0.4731	0.5119	0.5336
C5	0.5702	0.6528	0.3031	0.3893	0.3472	0.4298	0.6013	0.7111	0.2267	0.3222	0.2889	0.3987
C6	0.5239	0.5765	0.3941	0.4506	0.4235	0.4761	0.6114	0.7139	0.2336	0.3376	0.2861	0.3886
C7	0.2691	0.3692	0.2174	0.3178	0.6308	0.7309	0.4365	0.4876	0.3959	0.4581	0.5124	0.5635
C8	0.3817	0.4818	0.3304	0.4306	0.5182	0.6183	0.4489	0.5494	0.3500	0.4500	0.4506	0.5111

	C3						C4					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.4664	0.4881	0.4406	0.4731	0.5119	0.5336	0.6237	0.7266	0.2209	0.3251	0.2734	0.3763
C2	0.3260	0.4014	0.2117	0.3006	0.5986	0.6740	0.5129	0.5423	0.4406	0.4731	0.4577	0.4871
C3	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5599	0.6602	0.2895	0.3900	0.3398	0.4401
C4	0.3417	0.4418	0.2895	0.3900	0.5582	0.6583	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
C5	0.5239	0.5765	0.3941	0.4506	0.4235	0.4761	0.6328	0.7376	0.2079	0.3152	0.2624	0.3672
C6	0.5494	0.6271	0.3314	0.4126	0.3729	0.4506	0.6382	0.7404	0.2076	0.3109	0.2596	0.3618
C7	0.1972	0.2974	0.1388	0.2417	0.7026	0.8028	0.3875	0.4876	0.3364	0.4366	0.5124	0.6125
C8	0.3647	0.4648	0.3135	0.4137	0.5352	0.6353	0.5129	0.6130	0.3369	0.4371	0.3870	0.4871

	C5						C6					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.3654	0.4365	0.3031	0.3893	0.5635	0.6346	0.4350	0.4773	0.3941	0.4506	0.5227	0.5650
C2	0.3224	0.4234	0.2267	0.3222	0.5766	0.6776	0.2975	0.3979	0.2336	0.3376	0.6021	0.7025
C3	0.4350	0.4773	0.3941	0.4506	0.5227	0.5650	0.3881	0.4557	0.3314	0.4126	0.5443	0.6119
C4	0.2825	0.3832	0.2079	0.3152	0.6168	0.7175	0.2707	0.3712	0.2076	0.3109	0.6288	0.7293
C5	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
C6	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
C7	0.2487	0.3492	0.1814	0.2862	0.6508	0.7513	0.1732	0.2733	0.1203	0.2215	0.7267	0.8268
C8	0.3606	0.4607	0.3085	0.4089	0.5393	0.6394	0.2821	0.3825	0.2250	0.3264	0.6175	0.7179

	C7						C8					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.6320	0.7323	0.2174	0.3178	0.2677	0.3680	0.5194	0.6195	0.3304	0.4306	0.3805	0.4806
C2	0.5133	0.5720	0.3959	0.4581	0.4280	0.4867	0.4557	0.5562	0.3500	0.4500	0.4438	0.5443
C3	0.7076	0.8093	0.1388	0.2417	0.1907	0.2924	0.5362	0.6364	0.3135	0.4137	0.3636	0.4638
C4	0.5133	0.6135	0.3364	0.4366	0.3865	0.4867	0.3880	0.4881	0.3369	0.4371	0.5119	0.6120
C5	0.6626	0.7657	0.1814	0.2862	0.2343	0.3374	0.5410	0.6413	0.3085	0.4089	0.3587	0.4590
C6	0.7283	0.8289	0.1203	0.2215	0.1711	0.2717	0.6232	0.7242	0.2250	0.3264	0.2758	0.3768
C7	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.3589	0.4344	0.2972	0.3859	0.5656	0.6411
C8	0.5719	0.6576	0.2972	0.3859	0.3424	0.4281	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

Table 9 shows the sum of each column. The example of calculation for sum of column 1 as shown below.

$$Total_{C1,T^L} = 0.5000 + 0.2889 + 0.5129 + 0.2886 + 0.5702 + 0.5239 + 0.2691 + 0.3817 = 3.3354$$

Table 9: Sum of each column

	C1						C2					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.6633	0.7552	0.1932	0.2921	0.2448	0.3367
C2	0.2889	0.3571	0.1932	0.2921	0.6429	0.7111	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
C3	0.5129	0.5423	0.4406	0.4731	0.4577	0.4871	0.6311	0.7292	0.2117	0.3006	0.2708	0.3689
C4	0.2886	0.3894	0.2209	0.3251	0.6106	0.7114	0.4664	0.4881	0.4406	0.4731	0.5119	0.5336
C5	0.5702	0.6528	0.3031	0.3893	0.3472	0.4298	0.6013	0.7111	0.2267	0.3222	0.2889	0.3987
C6	0.5239	0.5765	0.3941	0.4506	0.4235	0.4761	0.6114	0.7139	0.2336	0.3376	0.2861	0.3886
C7	0.2691	0.3692	0.2174	0.3178	0.6308	0.7309	0.4365	0.4876	0.3959	0.4581	0.5124	0.5635
C8	0.3817	0.4818	0.3304	0.4306	0.5182	0.6183	0.4489	0.5494	0.3500	0.4500	0.4506	0.5511
Total	3.3354	3.8691	2.5997	3.1787	4.1309	4.6646	4.3588	4.9345	2.5517	3.1336	3.0655	3.6412

	C3						C4					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.4664	0.4881	0.4406	0.4731	0.5119	0.5336	0.6237	0.7266	0.2209	0.3251	0.2734	0.3763
C2	0.3260	0.4014	0.2117	0.3006	0.5986	0.6740	0.5129	0.5423	0.4406	0.4731	0.4577	0.4871
C3	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5599	0.6602	0.2895	0.3900	0.3398	0.4401
C4	0.3417	0.4418	0.2895	0.3900	0.5582	0.6583	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
C5	0.5239	0.5765	0.3941	0.4506	0.4235	0.4761	0.6328	0.7376	0.2079	0.3152	0.2624	0.3672
C6	0.5494	0.6271	0.3314	0.4126	0.3729	0.4506	0.6382	0.7404	0.2076	0.3109	0.2596	0.3618
C7	0.1972	0.2974	0.1388	0.2417	0.7026	0.8028	0.3875	0.4876	0.3364	0.4366	0.5124	0.6125
C8	0.3647	0.4648	0.3135	0.4137	0.5352	0.6353	0.5129	0.6130	0.3369	0.4371	0.3870	0.4871
Total	3.2694	3.7971	2.6196	3.1823	4.2029	4.7306	4.3679	5.0077	2.5397	3.1880	2.9923	3.6321

	C5						C6					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.3654	0.4365	0.3031	0.3893	0.5635	0.6346	0.4350	0.4773	0.3941	0.4506	0.5227	0.5650
C2	0.3224	0.4234	0.2267	0.3222	0.5766	0.6776	0.2975	0.3979	0.2336	0.3376	0.6021	0.7025
C3	0.4350	0.4773	0.3941	0.4506	0.5227	0.5650	0.3881	0.4557	0.3314	0.4126	0.5443	0.6119
C4	0.2825	0.3832	0.2079	0.3152	0.6168	0.7175	0.2707	0.3712	0.2076	0.3109	0.6288	0.7293
C5	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
C6	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
C7	0.2487	0.3492	0.1814	0.2862	0.6508	0.7513	0.1732	0.2733	0.1203	0.2215	0.7267	0.8268
C8	0.3606	0.4607	0.3085	0.4089	0.5393	0.6394	0.2821	0.3825	0.2250	0.3264	0.6175	0.7179
Total	3.0145	3.5304	2.6218	3.1724	4.4696	4.9855	2.8467	3.3579	2.5122	3.0595	4.6421	5.1533

	C7						C8					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.6320	0.7323	0.2174	0.3178	0.2677	0.3680	0.5194	0.6195	0.3304	0.4306	0.3805	0.4806
C2	0.5133	0.5720	0.3959	0.4581	0.4280	0.4867	0.4557	0.5562	0.3500	0.4500	0.4438	0.5443
C3	0.7076	0.8093	0.1388	0.2417	0.1907	0.2924	0.5362	0.6364	0.3135	0.4137	0.3636	0.4638
C4	0.5133	0.6135	0.3364	0.4366	0.3865	0.4867	0.3880	0.4881	0.3369	0.4371	0.5119	0.6120
C5	0.6626	0.7657	0.1814	0.2862	0.2343	0.3374	0.5410	0.6413	0.3085	0.4089	0.3587	0.4590
C6	0.7283	0.8289	0.1203	0.2215	0.1711	0.2717	0.6232	0.7242	0.2250	0.3264	0.2758	0.3768
C7	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.3589	0.4344	0.2972	0.3859	0.5656	0.6411
C8	0.5719	0.6576	0.2972	0.3859	0.3424	0.4281	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
Total	4.8291	5.4793	2.1876	2.8478	2.5207	3.1709	3.9223	4.6000	2.6615	3.3526	3.4000	4.0777

Table 10 shows the normalized weight of each factor. As an example, the calculation for Factor 1 (C1) shown as followed:

$$N_{11} = \left[\frac{0.5000}{3.8691}, \frac{0.5000}{3.8691}\right], \left[\frac{0.5000}{3.1787}, \frac{0.5000}{3.1787}\right], \left[\frac{0.5000}{4.6646}, \frac{0.5000}{4.6646}\right]$$

$$N_{11} = [0.1292, 0.1292], [0.1573, 0.1573], [0.1072, 0.1072]$$

Table 10: Normalized Weight

	C1						C2					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.1292	0.1292	0.1573	0.1573	0.1072	0.1072	0.1344	0.1531	0.0616	0.0932	0.0672	0.0925
C2	0.0747	0.0923	0.0608	0.0919	0.1378	0.1525	0.1013	0.1013	0.1596	0.1596	0.1373	0.1373
C3	0.1326	0.1402	0.1386	0.1488	0.0981	0.1044	0.1279	0.1478	0.0676	0.0959	0.0744	0.1013
C4	0.0746	0.1006	0.0695	0.1023	0.1309	0.1525	0.0945	0.0989	0.1406	0.1510	0.1406	0.1465
C5	0.1474	0.1687	0.0954	0.1225	0.0744	0.0921	0.1219	0.1441	0.0724	0.1028	0.0793	0.1095
C6	0.1354	0.1490	0.1240	0.1418	0.0908	0.1021	0.1239	0.1447	0.0746	0.1077	0.0786	0.1067
C7	0.0696	0.0954	0.0684	0.1000	0.1352	0.1567	0.0885	0.0988	0.1263	0.1462	0.1407	0.1548
C8	0.0987	0.1245	0.1039	0.1355	0.1111	0.1325	0.0910	0.1113	0.1117	0.1436	0.1238	0.1514
	C3						C4					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.1228	0.1285	0.1384	0.1487	0.1082	0.1128	0.1245	0.1451	0.0693	0.1020	0.0753	0.1036
C2	0.0859	0.1057	0.0665	0.0944	0.1265	0.1425	0.1024	0.1083	0.1382	0.1484	0.1260	0.1341
C3	0.1317	0.1317	0.1571	0.1571	0.1057	0.1057	0.1118	0.1318	0.0908	0.1223	0.0935	0.1212
C4	0.0900	0.1164	0.0910	0.1225	0.1180	0.1391	0.0998	0.0998	0.1568	0.1568	0.1377	0.1377
C5	0.1380	0.1518	0.1238	0.1416	0.0895	0.1006	0.1264	0.1473	0.0652	0.0989	0.0723	0.1011
C6	0.1447	0.1651	0.1041	0.1296	0.0788	0.0953	0.1274	0.1479	0.0651	0.0975	0.0715	0.0996
C7	0.0519	0.0783	0.0436	0.0760	0.1485	0.1697	0.0774	0.0974	0.1055	0.1369	0.1411	0.1686
C8	0.0961	0.1224	0.0985	0.1300	0.1131	0.1343	0.1024	0.1224	0.1057	0.1371	0.1065	0.1341
	C5						C6					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.1035	0.1236	0.0956	0.1227	0.1130	0.1273	0.1295	0.1421	0.1288	0.1473	0.1014	0.1096
C2	0.0913	0.1199	0.0715	0.1016	0.1157	0.1359	0.0886	0.1185	0.0764	0.1103	0.1168	0.1363
C3	0.1232	0.1352	0.1242	0.1421	0.1048	0.1133	0.1156	0.1357	0.1083	0.1348	0.1056	0.1187
C4	0.0800	0.1086	0.0655	0.0994	0.1237	0.1439	0.0806	0.1105	0.0679	0.1016	0.1220	0.1415
C5	0.1416	0.1416	0.1576	0.1576	0.1003	0.1003	0.1489	0.1489	0.1634	0.1634	0.0970	0.0970
C6	0.1416	0.1416	0.1576	0.1576	0.1003	0.1003	0.1489	0.1489	0.1634	0.1634	0.0970	0.0970
C7	0.0704	0.0989	0.0572	0.0902	0.1305	0.1507	0.0516	0.0814	0.0393	0.0724	0.1410	0.1604
C8	0.1021	0.1305	0.0973	0.1289	0.1082	0.1283	0.0840	0.1139	0.0735	0.1067	0.1198	0.1393
	C7						C8					
	T^L	T^U	I^L	I^U	F^L	F^U	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.1154	0.1337	0.0764	0.1116	0.0844	0.1160	0.1129	0.1347	0.0985	0.1284	0.0933	0.1179
C2	0.0937	0.1044	0.1390	0.1609	0.1350	0.1535	0.0991	0.1209	0.1044	0.1342	0.1088	0.1335
C3	0.1291	0.1477	0.0487	0.0849	0.0601	0.0922	0.1166	0.1383	0.0935	0.1234	0.0892	0.1137
C4	0.0937	0.1120	0.1181	0.1533	0.1219	0.1535	0.0843	0.1061	0.1005	0.1304	0.1255	0.1501
C5	0.1209	0.1397	0.0637	0.1005	0.0739	0.1064	0.1176	0.1394	0.0920	0.1220	0.0880	0.1126
C6	0.1329	0.1513	0.0423	0.0778	0.0539	0.0857	0.1355	0.1574	0.0671	0.0974	0.0676	0.0924
C7	0.0913	0.0913	0.1756	0.1756	0.1577	0.1577	0.0780	0.0944	0.0886	0.1151	0.1387	0.1572
C8	0.1044	0.1200	0.1044	0.1355	0.1080	0.1350	0.1087	0.1087	0.1491	0.1491	0.1226	0.1226

Table 11 shows the neutrosophic weight of each factor. As an example, the calculation neutrosophic weight for Factor 1 (C1) shown as followed:

$$W_1 = \begin{bmatrix} \dfrac{0.1292+0.1344+0.1228+0.1245+0.1035+0.1295+0.1154+0.1129}{8}, \\ \dfrac{0.1292+0.1531+0.1285+0.1451+0.1236+0.1421+0.1337+0.1347}{8}, \\ \dfrac{0.1573+0.0616+0.1384+0.0693+0.0956+0.1288+0.0764+0.0985}{8}, \\ \dfrac{0.1573+0.0932+0.1487+0.1020+0.1227+0.1473+0.1116+0.1284}{8}, \\ \dfrac{0.1072+0.0672+0.1082+0.0753+0.1130+0.1014+0.0844+0.0933}{8}, \\ \dfrac{0.1072+0.0925+0.1128+0.1036+0.1273+0.1096+0.1160+0.1179}{8} \end{bmatrix}$$

$$W_1 = [0.1215, 0.1363, 0.1032, 0.1264, 0.0938, 0.1109]$$

Table 11: Neutrosophic Weight

	Weight					
	T^L	T^U	I^L	I^U	F^L	F^U
C1	0.1215	0.1363	0.1032	0.1264	0.0938	0.1109
C2	0.0921	0.1089	0.1020	0.1252	0.1255	0.1407
C3	0.1236	0.1386	0.1036	0.1262	0.0914	0.1088
C4	0.0872	0.1066	0.1012	0.1272	0.1275	0.1456
C5	0.1328	0.1477	0.1042	0.1262	0.0843	0.1025
C6	0.1363	0.1507	0.0998	0.1216	0.0798	0.0974
C7	0.0723	0.0920	0.0881	0.1140	0.1417	0.1595
C8	0.0984	0.1192	0.1055	0.1333	0.1141	0.1347

The deneutrosophication formula was used to obtain crisp weight for each factor shown in Table 12. The example of calculation for Factor 1 (C1) shown below:

$$D(C1) = \left(\left(\frac{0.1215+0.1363}{2} \right) + (0.1264)\left(\frac{0.1032+0.1264}{2} \right) - (1-0.1109)\left(\frac{0.0938+0.1109}{2} \right) \right) = 0.1498$$

Table 12: Ranking of Flash Floods' Factors

Factor		Weight	Rank
C1	Poor Drainage System	0.1498	4
C2	Dam and Levee Failure	0.0971	6
C3	Urbanization	0.1535	3
C4	Land Use Pattern	0.0929	7
C5	Rain Intensity	0.1681	2
C6	Rain Duration	0.1717	1

C7	Slow Moving Thunderstorm	0.0581	8
C8	Soil Erosion	0.1185	5

4.3 Comparative Analysis

In this study, the comparative analysis of different aggregation operators which are interval neutrosophic weighted average (INWA), interval neutrosophic geometric average (INWG), interval neutrosophic average (INA), and interval neutrosophic geometric (ING) operators are presented for solving the flash floods problem. Linguistic terms are used to facilitate comparisons between subject factors because decision-makers are more familiar with using linguistic terms than providing exact crisp evaluations. Figures 2 and 3 show the ranking results using INWA and INWG respectively.

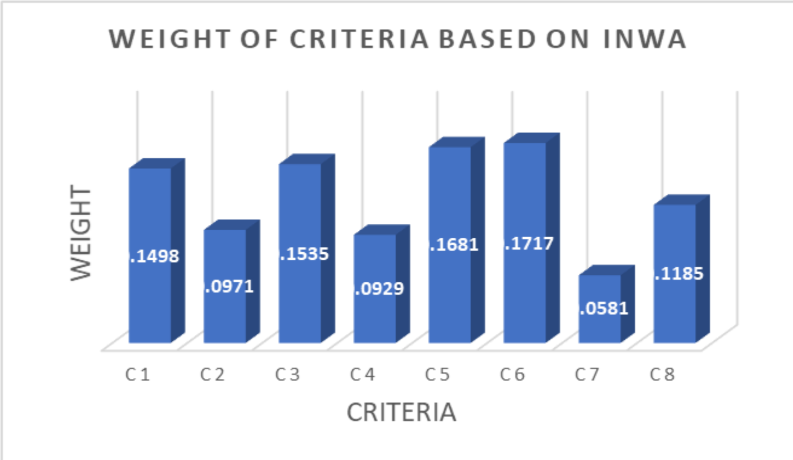

Figure 2: Weight of factors based on INWA

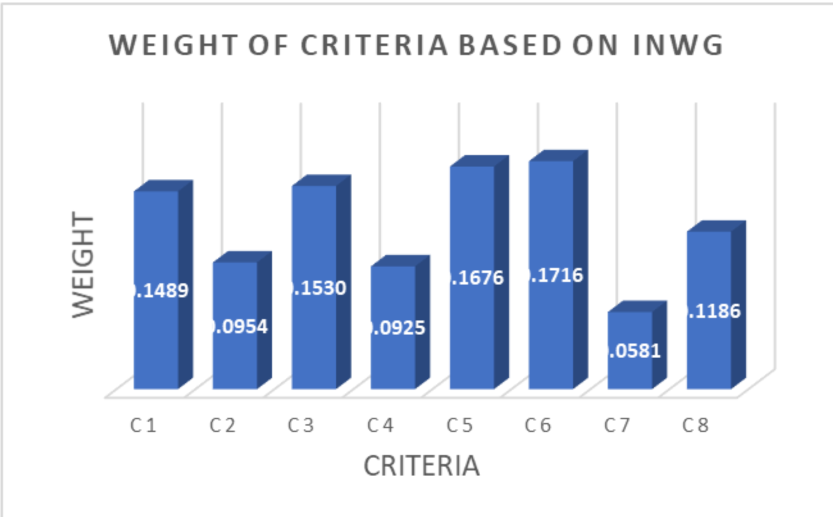

Figure 3: Weight of factors based on INWG

According to Figure 2, the results obtained by using the INWA operator show that the rain duration has the greatest weight (0.1717). This means that the duration of rain was the most important factor in causing flash floods in Penang. While slow-moving thunderstorms have the lowest weight (0.0581), they are the least important cause of flash floods in Penang. Surprisingly, when the ranking results of flash flood factors using the INWG operator are compared, the highest priority remains the same, which is the rain duration with a weightage of 0.1716. This proves that the rain duration is the most important factor in causing flash floods. Furthermore, we compare with the INA and ING, where the weights of decision makers are assumed to be the same. Besides that, we also compare the ranking of factors with the INA and ING where the weights of decision makers are assumed to be the same, which is $w_{DM} = (0.2, 0.2, 0.2, 0.2, 0.2)^T$. For both INA and ING operators, the obtained results show that the rain duration factor is the most important factor in causing the flash flood. Figures 4 and 5 show a bar chart of the obtained factor ranking order using INA and ING.

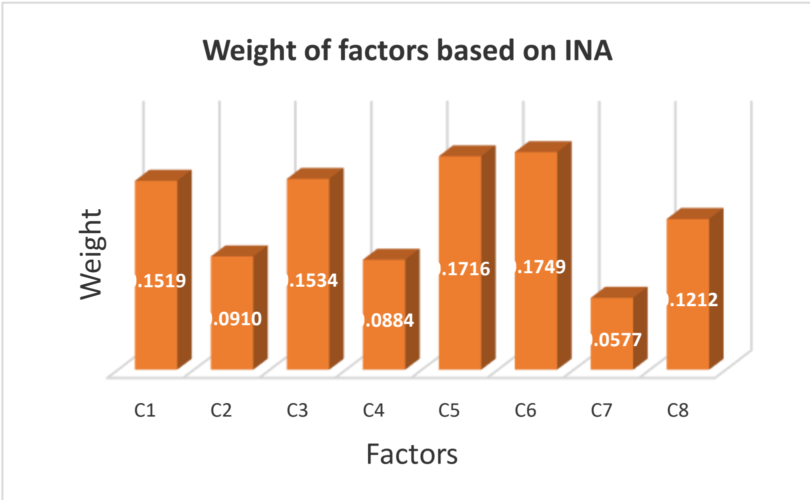

Figure 4: Weight of factors based on INA

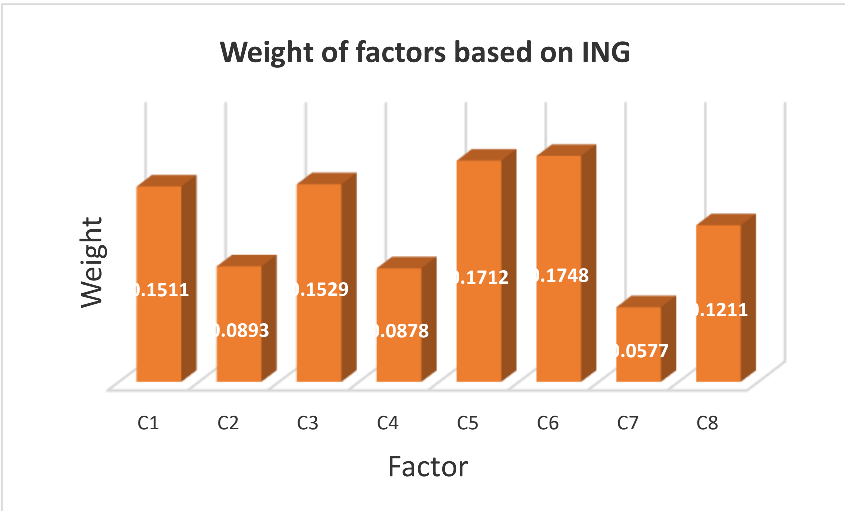

Figure 5: Weight of factors based on ING

The result of the comparative analysis of INWA, INWG, INA, and ING based on different weights and equal weights of each decision-maker are summarized in Table 12. Using INWA and INWG with different weights of decision-makers, the ranking of factors of flash floods in Penang has been determined. It can be noted that the weight of each decision-maker should be measured according to some characteristics such as their positions, working experience, and knowledge about that particular case study. This is an important point to emphasize that the weight of each decision-maker should be measured based on the characteristics mentioned so that the results obtained are more accurate and reliable.

The aggregation operator is also important, particularly in decision-making problems, because it provides a high-level view of data prior to analysis. One of the most effective and simple methods for decision-making problems is to use aggregation functions. The obtained ranking of factors is completely consistent when employing the IVN-AHP method with INWA operator and any other aggregation operators such as INWG, INA and ING operators. This validates the proposed method's applicability in solving decision making problems. In addition, the INWA operator is suitable to apply in this case study since it is easy to explore and understand. Therefore, the INWA aggregation operator is recommended to use in this study.

Table 12: Summary Table for Comparative Analysis

Criteria		Different Weight		Same Weight		Rank
		INWA	INWG	INA	ING	
C1	Poor Drainage System	0.1498	0.1489	0.1519	0.1511	4
C2	Dam and Levee Failure	0.0971	0.0954	0.0910	0.0893	6
C3	Urbanization	0.1535	0.1530	0.1534	0.1529	3
C4	Land Use Pattern	0.0929	0.0925	0.0884	0.0878	7
C5	Rain Intensity	0.1681	0.1676	0.1716	0.1712	2
C6	Rain Duration	0.1717	0.1716	0.1749	0.1748	1
C7	Slow Moving Thunderstorm	0.0581	0.0581	0.0577	0.0577	8
C8	Soil Erosion	0.1185	0.1186	0.1212	0.1211	5

5. Conclusion

As a conclusion, the interval neutrosophic AHP method based on the INWA operator has been proposed in this study to determine the most important factor of flash floods in Penang. Eight factors of the flash flood are considered in this study which are the rain intensity, rain duration, poor drainage system, dam and levee failure, urbanization, slow-moving thunderstorm, soil erosion, and land use pattern. By using the AHP method with the INWA operator, the following ranking order of factors is established: rain duration, rain intensity, urbanization, poor drainage system, soil erosion, dam and levee failure, land use pattern and slow-moving thunderstorms. The obtained results are consistent when evaluated with various aggregation operators such as INA, ING, and INWG.

The recommendation for future research is to consider the other factors of flash floods, as there are numerous factors that can be used, whether from a literature review or an expert's perspective. The other factors can provide additional information regarding the flash flood factor in Penang. In addition, future researchers can use this study as a reference to determine the factors contributing to flash floods in other states. Besides, as a further extension of this research, the implemented IVN-AHP method based on the INWA aggregation operator can be used for different types of case studies that involve the decision-making problem such as determining the ranking's factor of road accidents, analyzing the IT project prioritization for oil and gas company, and measuring patients' priorities. Plus, this research also can be extended by implementing another aggregation operator in the IVN-AHP method such as Interval Neutrosophic Ordered Weighted Averaging (INOWA), Interval Neutrosophic Ordered Weighted Geometric (INOWG), and Interval Neutrosophic

Prioritized Ordered Weighted Averaging (INPOWA) in the future.

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