Chapter -6

SELECTION OF FLOOD CONTROL PROJECT AND COMPARISION OF MCDM

Evaluation Selection of flood control project by using Fuzzy PROMETHEE and Comparison of some multi criteria decision making tools.

6.1 INTRODUCTION

In this chapter we discussed flood management issue, which is explicitly in the choice of flood control projects utilizing multi-criteria decision making (MCDM) techniques that begun in mid 1990s. For instance, Willet and Sharda (1991) have utilized the analytic hierarchy process (AHP) technique for the determination of flood control project. Moreover, Tkach and Simonovic (1997) have proposed spatial compromise programming (SCP) technique to produce, assess, and rank a lot of potential flood security choices. Raju and Pillai (1999) have made a correlation of five MCDM strategies, to be specific, ELECTRE-2, PROMETHEE-2, AHP, CP and EXPROM-2 to choose the best store setup for the contextual investigation of Chaliyar stream basin, Kerala, India. Besides, Bana e Costa et al. (2004) introduced a multi-criteria assessment of flood control measures to assess flood control alternatives for the catchment of Livramento Creek in Setubal Peninsular in Portugal. Also, Srdjevic et al. (2004) utilized TOPSIS to rank choice alternative (situations) of store framework and used the entropy strategy to weighting the significance of execution records. At that point, Maragoudaki and Tsakiris (2005) exhibited the execution of PROMETHEE, one of the most proficient MCDM outranking techniques so as to accomplish the ideal flood relief plan for a stream basin. Zamri N et al., (2013) contributed A Type-2 modified fuzzy TOPSIS methodology in the selection of the best flood control project alternative. Brahma A. K et al. (2019) utilized fuzzy AHP and fuzzy VIKOR for selecting flood control alternatives.

Plainly there has not been adequate investigation of flood control alternative selection with the fuzzy MCDM approach. Most of past studies deals with traditional MCDM techniques. Therefore, so as to fill the gap in the alternative selection, we proposed flood control alternative selection, that information are estimated dependent on information gathered by questionnaires from the experts in triangular fuzzy number form. In this proposed system, the decision maker’s opinion on the weighting of criteria is calculated by a fuzzy AHP methodology. The ranking of alternative is determined by Fuzzy PROMETHEE technique.

The rest of the chapter is presented as follows: In section 6.2, review of relevant literature and steps in fuzzy PROMETHEE method. In section 6.3, a numerical example of how fuzzy PROMETHEE could help to evaluate and rank flood control project alternatives is presented, in section 6.4 Comparisons among MCDM methods in flood control alternatives, in section 6.5 sensitivity analysis and in Section 6.5 conclusion

6.2 FUZZY PROMETHEE

PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations) is an outranking strategy which starting references are set up by Brans et al. (1984), Brans and Vincke(1985), and Brans et al. (1986). The PROMETHEE technique is favored in ranking and choosing alternatives because of its power in performances of alternatives and thinks about it in the composite ranking. Similarly as in other MCDM strategies, there is a fuzzy expansion of the PROMETHEE strategy when managing with uncertainty and subjective information. Fuzzy PROMETHEE has been contributed in varied fields such as health care management (Amaral et al., 2014), waste treatment solution selection (Lolli et al., 2016), Yilmaz and Dagdeviren (2011) contributed fuzzy PROMETHEE and goal programming for equipment selection, material handling equipment selection problems. Tuzkaya et al. (2010), system information outsourcing Chen et al. (2011), the ideal eco-innovation determinations for a down to earth building site Chou et al. (2007) , Geldermann and Rentz (2001) contributed fuzzy PROMETHEE for ecological evaluation and built up a graphical sensitivity analysis. Wang et al. (2008), contributed for choosing redistributed providers. Bilsel et al. (2006) displayed fuzzy PROMETHEE for ranking medical clinic sites. Geldermann et al. (2000) contributed fuzzy PROMETHEE with trapezoidal fuzzy interval numbers and show an application for the ecological assessment of iron and steel ventures. Shakhsi-Niaei et al. (2011) fixed the fuzzy PROMETHEE into a Monte Carlo simulation outline so as to rank activities. Zhou et al. (2009) contributed fuzzy PROMETHEE for the issue with pipe condition evaluations. M. Gul et al. (2018) contributed fuzzy rationale

PROMETHEE dependent on trapezoidal fuzzy interval numbers strategy for material determination issues.

Albadvi et al. (2007) applied PROMETHEE to stock trading purposes. So as to choose the best stocks at the correct minute, and therefore yield the maximum return, dealers regularly are looked with numerous, clashing criteria. Thus, they should pick inclinations in these criteria and judge in like manner. PROMETHEE was appeared to effectively take into account such inclination and yielded brilliant outcomes. Duvivier et al. (2013) used PROMETHEE strategy to address issues with industrial scheduling. They demonstrated that PROMETHEE was a successful method for tending to the multi-criteria, particular issue of planning

Fuzzy PROMETHEE has likewise observed enhancements in various variations, that is adaptations (PROMETHEE I, II, III, IV, V, VI), and extensions as seen in (Xiaojuan et al 2014); (Ting-Yu, 2014); (Sonia et al 2013); (Wei-xiang, et al . 2010)

This chapter we applied a mix of PROMETHEE I and II. PROMETHEE I deals with a partial ranking of alternatives (Vincke et al, 1985); (Ting-Yu, 2014); (Sonia et al 2013), the sum of indices, firstly determines the preference of alternative *n* over the other alternatives measured. This is referred to as the 'outgoing flow' $\emptyset^{+}(a)$, and implies the relative good performance of *n* over the other alternatives. The alternative with the highest 'outgoing flow' is marked the best in the evaluation. Likewise, the sum of indices $\prod(a,b)$ is calculated to signify the preferences of all other alternatives measured against *n*. This is likewise indicated as the 'incoming flow'$\emptyset^{-}(a)$, and suggests the reliance of alternative n in connection to the rest of the alternatives. PROMETHEE II anyway presents a net flow which means the distinction between the outgoing and the incoming flow and serves to understand a full ranking. The alternative with the most noteworthy net flow $\emptyset(a)$ is thus best alternatives.

6.2.1 The methodology for implementation of the method is given in following steps:

Step1: Determine alternatives, criteria and decision maker

Suppose that there are m alternatives, k criteria and n decision- makers.

Step 2: determination of linguistic variable and linguistic term and corresponding fuzzy number.

This step we consider five linguistic variables and its associated linguistic term contributed by (Hwang et al., 1992) , namely "equal important", " less important", "fairly important", "very important" and " absolute important" which were expressed in term of triangular fuzzy number, to assess the important weights of criteria. Also the evaluators used the linguistic term (Table 6.1) "very low", "low", "medium", "high" and "very high" to express the expert's opinion in rating of alternatives. The linguistic term are translated into fuzzy number are shown in the figure 6.1.

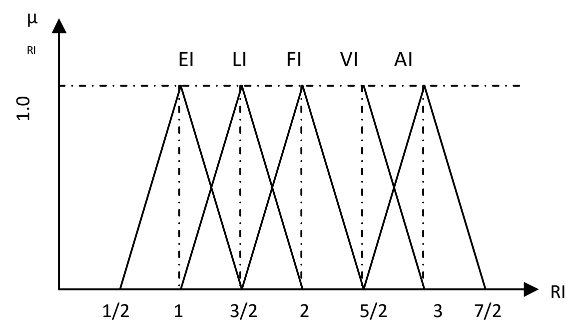


Figure 6.1. Linguistic scale relative importance (G. Tuzkaya et al. 2010)

Table 6.1

Linguistic scale for importance (Kahraman et al., 2006).

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal (JE)	(1, 1, 1)	(1, 1, 1)
Equally important (EI)	(1/2, 1, 3/2)	(2/3, 1, 2)
Less important (LI)	(1, 3/2, 2)	(1/2, 2/3, 1)
Fairly important (FI)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very Important (VI)	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolute Important AI)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5

Step 3: Determination of Importance Criterion Weights

Decision makers determines the importance weights $\widetilde{w}_j$ of each criterion by using the Fuzzy AHP method and linguistic terms with their corresponding TFNs .shown in figure 2. And linguistic scale in Figure -6.2

Here w_j denotes the weights of the jth criterion C_j based on the linguistic term preference assigned by a decision maker.

It is noted that each weight $\widetilde{w}_j^k = (w_{j1}^k, w_{j2}^k, w_{j3}^k)$ is expressed as a TFN.

$$\widetilde{W} = [\widetilde{w}_1, \widetilde{w}_2, \dots, \widetilde{w}_n],\ j= 1, 2, \dots, n \tag{6.2}$$

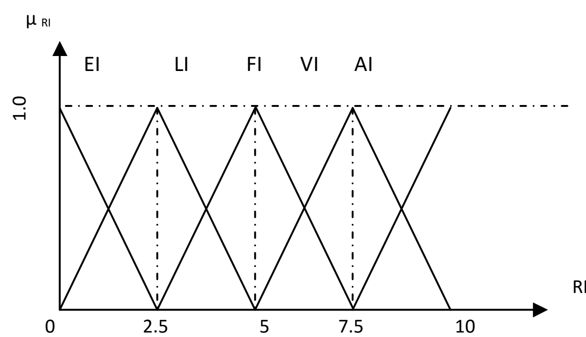


Figure6. 2 Linguistic scales for evaluation

Table 6.2

Linguistic terms for Alternatives Ratings

Linguistic terms	Triangular fuzzy number
Very Low (VL)	(0.0, 0.0, 2.5)
Low (L)	(0.0, 2.5, 5.0)
High (H)	(2.5, 5.0, 7.5)
Very High (VH)	(5.0, 7.5, 10.0)
Extremely High (EH)	(7.5, 10.0, 10.0)

Step 4: Aggregate the decision maker's estimation.

For the aggregation of experts decisions, geometric mean operation were used. Geometric mean operation were applied in many studies for MCDM (Davies, 1994)

Fuzzy rating of all decision- makers are described as TFNs

$\tilde{A}_k = (f_k^l, f_k^m, f_k^u)$, where k=1,2, …K , the the aggregated fuzzy rating can be determined as $\tilde{A} = (f^l, f^m, f^u)$, k=1, 2, .. K

$$f^l{}_{ij} = \left(\prod_{k=1}^{k} f^l{}_{ijk}\right)^{1/k}, \quad f^m{}_{ij} = \left(\prod_{k=1}^{k} f^m{}_{ijk}\right)^{1/k}, \; f^u{}_{ij} = \left(\prod_{k=1}^{k} f^u{}_{ijk}\right)^{1/k} \quad (6.3)$$

Step 5: Construction of the fuzzy decision matrix

The fuzzy decision matrix for the alternatives $\widetilde{D}$ is constructed as follows:

$$\widetilde{D} = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}, \text{ where i=1, 2, …,m : j=1, 2, … n} \quad (6.4)$$

Where $\tilde{x}_{ij}$ is the rating of alternatives A_i under the criterion C_j both expressed in TFNs. The TFNs of K decision maker k is $\tilde{x}_{ij}^k = (f^{l}{}_{ij}^{k}, f^{m}{}_{ij}^{k}, f^{u}{}_{ij}^{k})$

Step 6: Normalized the Fuzzy decision matrix.

The aggregated fuzzy decision matrix from step 5 is normalized using linear scale transformation to bring the various criteria scales into comparable scale. The normalized Fuzzy decision matrix $\tilde{R}$ can be obtained as

$$\tilde{R} = [r_{ij}]_{mxn} \quad i = 1, 2, \dots, m; \;\; j = 1, 2, \dots n \quad (6.5)$$

Where $\tilde{r}_{ij} = \left(\frac{f^l{}_{ij}}{f^{u*}{}_j}, \frac{f^m{}_{ij}}{f^{u*}{}_j}, \frac{f^u{}_{ij}}{f^{u*}{}_j}\right)$ and $f^{u*}{}_j = \max_i f^u{}_{ij}$

Step-7: Construct weighted normalized Fuzzy decision matrix

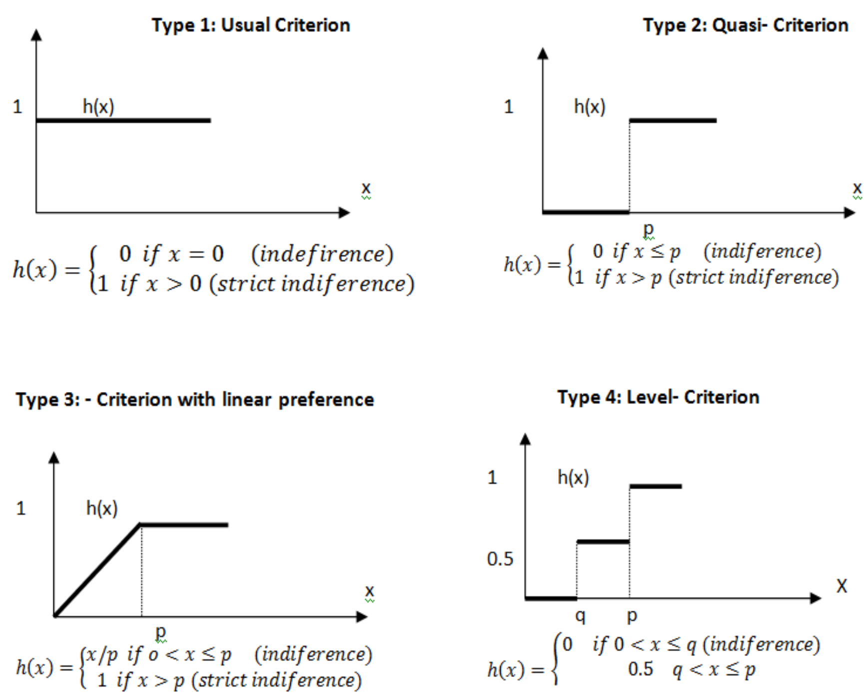
Taking into consideration the different weight of each criterion, the weighted normalized decision matrix is evaluated by multiplying the importance weights of evaluation criteria and the values in the normalized fuzzy decision matrix. The weighted normalized decision matrix V is defined as

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{mxn} \quad i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \qquad (6.6)$$

$\tilde{v}_{ij} = \tilde{r}_{ij}(.)W$, where W is the criterion weighted calculated by using Fuzzy AHP

Step 8: De fuzzy The normalized triangular fuzzy number $\widetilde{X}_i = ({f^l}_i, {f^m}_i, {f^u}_i)$, is defuzzified by the following method

$$Crisp(\tilde{X}_i) = ({f^l}_i + 2{f^m}_i + {f^u}_i)/4 \qquad (6.7)$$



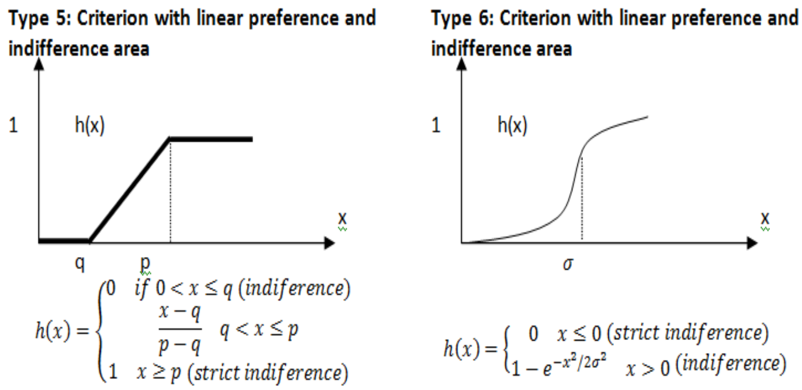


Figure 6.3 General preference functions of PROMETHEE

Step 9: Construction of the fuzzy preference function

The fuzzy preference function $\tilde{p}_j$ is calculated to describe the decision maker's preference among the pairs of alternatives. The list of six general criterion functions is described in the Figure 6.3. Where h(x)=P(a,b) if x ≥ 0. And h(x) = P(b,a) if x≤ 0

Let us consider a finite set of alternatives where A={a_1, a_2, …, a_n} and F= {g_1, g_2, …,g_n} a finite set of criterion on which the ranking of alternatives to be evaluated. With each of criterion g_j, j=1,2,…, m, is assigned a weight w_j reflecting its relative importance.

The usual- criterion function (Type-1) is used in the paper which (see Figure 6.3) is defined in equation (22) below

$$P_j(a,b) = \begin{cases} 0, & \tilde{x}_{aj} \le \tilde{x}_{bj} \\ 1 & \tilde{x}_{aj} > \tilde{x}_{bj} \end{cases} \quad \text{j=1, 2 , …,k} \qquad (6.8)$$

Step 10: Computation of weighted aggregated preference function

Out ranking degree$\prod(a,b)$, for each pair of alternatives $(a,b) \in AxA$ is computed in the following way:

$$\prod(a,b) = \frac{1}{W}\sum_{j=1}^{m} w_j\, h_j(a,b) \tag{6.9}$$

$W = \sum_j^m w_j$ and $h_j(a,b)$ are number between 0 and 1 that are a function of $g_i(a) - g_j(b)$

Step 11: Computation of the outgoing, incoming and net flows

In this step each alternatives is associated to (n-1) alternatives where the result is either a positive or negative flow. The value of outgoing flow $\emptyset^{+}(a)$ and incoming flow $\emptyset^{-}(a)$ are calculated by equation (24) and (25), n refers to the number of alternatives.

$$\text{Outgoing flow:} \quad \emptyset^{+}(a) = \frac{1}{n-1}\sum_{a \neq y} \pi(a,y) \qquad \forall\, a, y \in A \tag{6.10}$$

Where $\emptyset^{+}(a)$ indicates the sum of preference that **a** is greater to other alternatives. The greater the $\emptyset^{+}(a)$, the better the alternatives **a**.

$$\text{incoming flow:} \quad \emptyset^{-}(a) = \frac{1}{n-1}\sum_{a \neq y} \pi(y,a) \qquad \forall\, a, y \in A \tag{6.11}$$

Where $\emptyset^{-}(a)$ indicates the sum of preference that other alternatives is greater to a. The smaller the $\emptyset^{-}(a)$, the better the alternatives a.

Step 12: Partial Ranking:

The higher the outgoing flow and the lower the incoming flow, the better the alternative performance. This is pictorially illustrated via partial preorder (PROMETHEE I) if alternative **a** is superior to alternative **b** (*aPb*), then at least one of the condition of Eq^{n}-(6.12) is satisfied (Tuzkzya et al. 2010; M. Gul et al. 2018)

(*aPb*), if : $\emptyset^{+}(a) > \emptyset^{+}(b)$ and $\emptyset^{-}(a) < \emptyset^{-}(b)$ OR

$\emptyset^{+}(a) > \emptyset^{+}(b)$ and $\emptyset^{-}(a) = \emptyset^{-}(b)$ OR (6.12)

$\emptyset^{+}(a) = \emptyset^{+}(b)$ and $\emptyset^{-}(a) < \emptyset^{-}(b)$ OR

PROMETHEE I assessment permits indifference and incomparability circumstances. Therefore some of the time partial rankings can be acquired. In the indifference circumstance (*aIb*), two alternatives a and b have the same similar outgoing and incoming flow (Tuzkzya et al. 2010; M. Gul et al. 2018)

$$aIb \text{ if } : \quad \emptyset^{+}(a) = \emptyset^{+}(b) \text{ and } \emptyset^{-}(a) = \emptyset^{-}(b) \tag{6.13}$$

Two alternatives are viewed as incomparable, *aRb*, if alternative at is superior to alternative an as far as outgoing flow, while the incoming flow show the reverse (Tuzkzya et al. 2010; M. Gul et al. 2018)

$$aRb \text{ if : } \quad \emptyset^{+}(a) > \emptyset^{+}(b) \text{ and } \emptyset^{-}(a) > \emptyset^{-}(b) \text{ OR}$$

$$\emptyset^{-}(a) < \emptyset^{-}(b) \text{ And } \emptyset^{-}(a) < \emptyset^{-}(b) \text{ OR} \tag{6.14}$$

Step 13: Ranking Establishment.

In this step full ranking is provided by PROMETHEE II. In order to find complete ranking net flow of alternatives can be calculated by equation (29). If the alternatives a's net flow have higher than alternative b, net flow this means **a** out rank alternative **b**.

$$\emptyset^{net}(a) = \emptyset^{+}(a) - \emptyset^{-}(a) \tag{6.15}$$

6.3 APPLICATION OF THE MODEL TO CASE ILLUSTRATION

6.3.1 Study Area

The (Bodoland Territorial Area District) BTAD consist of four contiguous districts namely kokrajhar, Chirang, Baksa and Udalguri. Within state Assam, India The geographical Boundary of BTAD lies between 26° 7'12'' N to 26° 7'50'' N latitude and 89° 47'40'' E to 92° 18'30'' E longitude and it is the north-western part of Assam.

BTAD is situated on the north bank of Brahmaputra waterway in Assam in the North-East India and the foothills of Bhutan and barderining North Bengal. The covering an area of 8851sqkm, The total population of the study area is 31,51,047 with a density of 325 per sq. km. The average temperature is about 24 °C and its seasonal temperature ranges from 9 °C to 35 °C and maximum temperature often exceeds 36°C . The annual rainfall varies from 1600mm to 2680 mm.

There are about more than 50 numbers of tributaries and sub- tributaries passing through BTAD and most of which originates from the Himalaya Mountain, Bhutan foot hills and Arunachal Pradesh. These tributaries during rainy season become flashy, cause flood and erosion in various part of BTAD. However, the area has experienced regularly repeated flood damages. There is a huge economic loss due to the flood damage in the last decade.

River system under the BTAD comprises of various tributaries and sub-tributaries are shown in the Figure 6.4

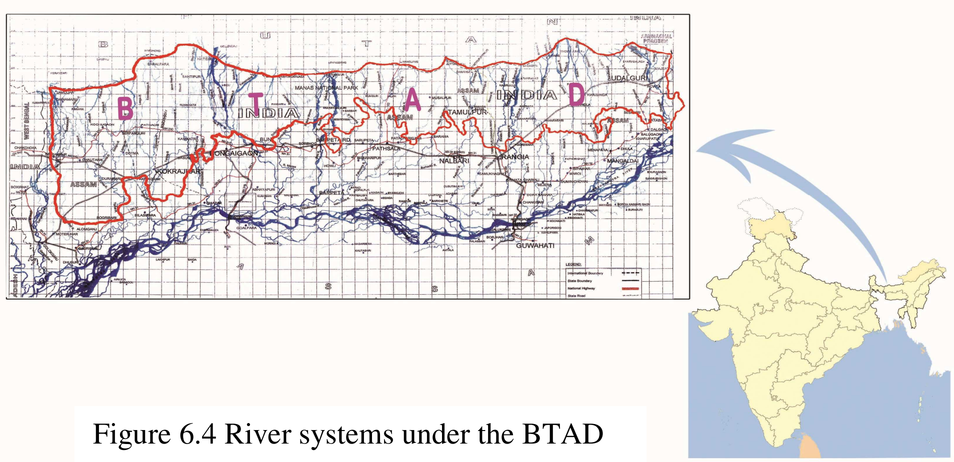


Figure 6.4 River systems under the BTAD

6.3.2 Flood Control Alternatives

Flood control and flood damage decrease are significant destinations of river basin planning Flood control and floodplain the management require hydrologic and water powered analysis of floods. This analysis decides inundated areas, flood height, and attributes of required water driven structures for flood control or flood damage decrease. The average necessities for floodplain investigation and arranging incorporate (Hoggan, 1997; Mays et al., 1996):

Flood control alternatives can be arranged into two groups: structure and nonstructural. Structural alternatives decides to customary flood damage decrease by physical implies. In other words, the development of flood control facilities can be alluded as structural measures. In this section we need to determine the best flood control project alternative selection by using PROMETHEE II. The significant measures for structural reduction of flood damage, the following four alternatives are considered. (Karamouzet al 2003)

A1- Dams and reservoirs: Flood control dams might be developed over the water way to store floodwaters and to lessen the size of the flood and the downstream phase of the flood. The deposited floodwater can be assigned to various purposes agriculture and generation of electricity. Flood control repositories additionally can change the hydraulic character and stream system in downstream of the reservoir.

A2- Levees and floodwalls: Levees and floodwalls are the most established and regularly utilized strategies for security against floods. Levees or barriers are developed parallel to streams to anticipate flood of floodwater to the floodplain. Floodwalls are typically built from concrete and play out the equivalent work as levees they can be built at a relatively low cost with materials available at side

A3- Channel Improvement / dredging: This is one most significant technique for channel adjustment. Method adopted for flood control measures so as to expand the flood conveying limit of a river. This methodology empowers the water to river off quicker and subsequently declines the stature and length of floods and decrease the recurrence of flood damage.

A4- Flood diversion: The flood water can be diverted through an artificial channel that can increase the flood discharge and can minimize the damage.

Since flood control choices have advantage and disadvantage of every criterion, the choice procedure must be assessed cautiously in light of the fact that every usage obviously includes huge investment. The impact on environment and social additionally perhaps as gigantic as cost for the execution project. Consequently, the determination of flood control alternatives must be considered from various points to achieve an optimum solution or holistic approach. The decision criteria and sub criteria (factors) are shown in the figure 6.5.

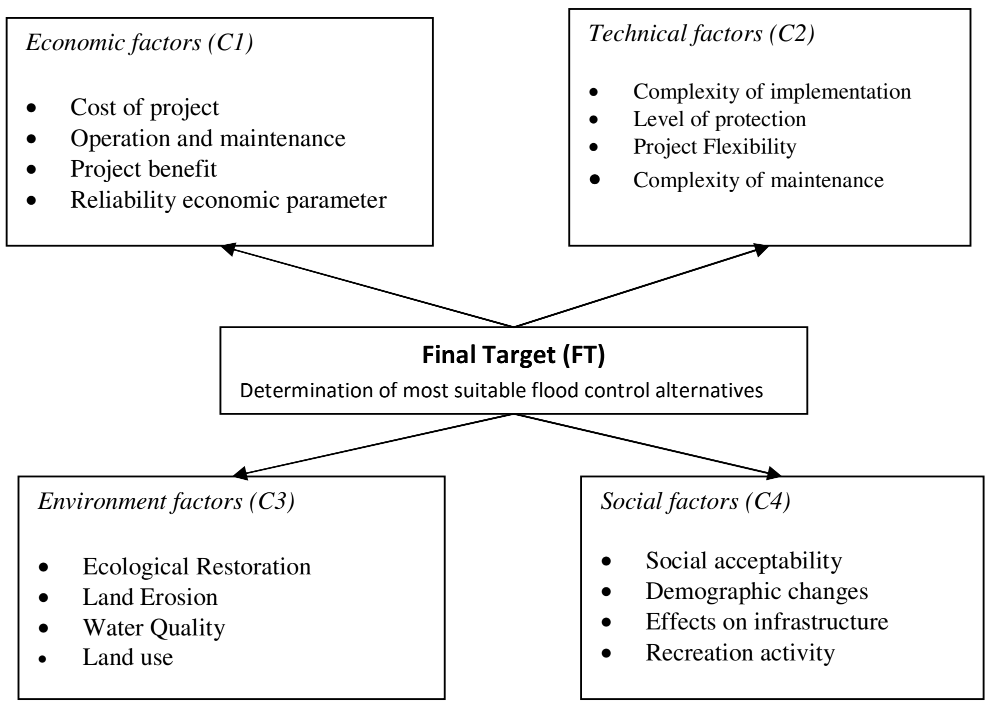


Figure 6.5. Decision Main criteria and sub criteria.

The first evaluation criteria (**C1-Economic factor**) are the economical considerations. The estimated total cost for project, operation and maintenance cost per year. It concerns the long-term benefit of the project such as flood damage reduction, socio-economic benefit, national/ regional economic development etc.

The Second criterion (**C2- Technical factors**) this criteria estimated lifetime of the alternative. The flexibility to the local condition, identified with flood magnitude and long terms insurance of the venture at the flood chance region and close by zone.

Third criterion (**C3- Environment factors**) is environmental consideration. This criterion related to Effect on hydrological surface and groundwater levels, Impacts on flora and fauna, endangered species habitat, Impacts on area of agriculture soil and soil contamination long term sustainability development

Fourth criterion (**C4- Social factors**) is social consideration. The public perception about risk to community life, health and displacement Effects on social structure, geographic and demographic distributions of income and employment effects to the infrastructure, historical places

The entire criterion that used in this study referred to various articles as follows: Willet and Sharda (1991), Bana e Costa, *et al.*, (2003), Brouwer and van Ek (2004), Maragoudaki and Tsakiris (2005), Levy (2005) and Zhou, *et al.*, (2007). Zamri et al.2013

The proposed hierarchical structure of the alternatives and criterion are shown Figure 6.6.

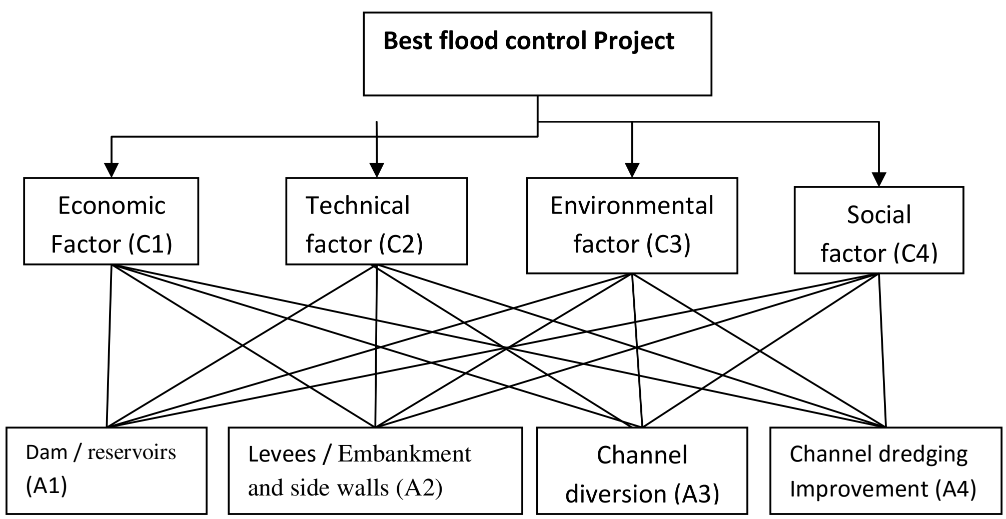


Figure 6.6 Hierarchical structures for ranking of alternatives

Following determining the alternatives and the criterion weight , calculation of criteria is done with F-AHP for that an expert committee, so as to choose the most favored flood control alternatives, an expert board of trustees of four decision makers E1, E2, E3, E4 has been framed. These experts are from different departments one Sub Divisional Circle Officer (SDCO), another from District Disaster Management Authority (DDMA), two are executive Engineers under the water resource department one from irrigation department. Based on the literature regarding the evaluation flood control alternatives we discussions with the experts and criterion economic factor(C1), technical factor(C2) , environmental factor(C3) and social factor (C4) criteria are identified which is shown in the figure 6.5.

To procure the judgments of the Experts on the four alternative flood control project and on the weights of the four criteria, several interviews are arranged with the experts. The experts were approached to give the rate pair wise comparison of criteria with every rule recognized in Figure 6.1 as per the linguistic variable according to table 6.1 and the rating obtained is exhibited in the table 6.3

Table 6.3

Pair wise comparison criterion Rating

Criteria	Experts	C1	C2	C3	C4
C1	E1	JE	FI	EI	EI
	E2	JE	EI	LI	EI
	E3	JE	VI	FI	VI
	E4	JE	JI	EI	JI
C2	E1		JE	EI	FI
	E2		JE	JI	VI
	E3		JE	VI	EI
	E4		JE	AI	EI
C3	E1			JE	EI
	E2			JE	LI
	E3			JE	VI
	E4			JE	AI
C4	E1				JE
	E2				JE
	E3				JE
	E4				JE

The linguistic variable are transformed to the corresponding Triangular Fuzzy Numbers (TFNs) and aggregating the elements of synthetic pair wise comparison matrix by using Eq^n-(6.3) Geometric mean method suggested by[Lee 2009] as given in table 6.4

Table 6.4

Fuzzy geometric mean of pair wise comparison of Criteria

	C1			C1			C3			C4		
C1	(1	1,	1)	(1.10,	1.49,	1.83)	(0.78,	1.31,	1.83)	(0.88,	1.25,	1.61)
C2	(0.54,	0.66,	0.90)	(1	1,	1)	(1.25,	1.65,	1.99)	(0.93,	1.49,	2.02)
C3	(0.54,	0.75,	1.27)	(0.50,	0.60,	0.79)	(1	1,	1)	(1.25,	1.83,	2.36)
C4	(0.62,	0.79,	1.12)	(0.49,	0.66,	1.07)	(0.42,	0.54,	0.79)	(1	1,	1)

The transformed objective data are then used to determine the criteria weight by F-AHP method proposed by Chang (1996) through the (from Chapter 2 of Eq^n-(2.2) to Eq^n-(2.8)) and values are presented in the table 6.5.

Table 6.5

Final priority weights of Main criteria and Sub criteria

	Criteria	Weights
C1	Economic factor	0.3052
C2	Technical factor	0.2895
C3	Environmental factor	0.2503
C4	Social factor	0.1551

Next is the ranking of the alternatives by presenting the applicability of those PROMETHEE I and II MCDM using criterion weights C1= 0.3052, C2=0.2895, C3=0.2503, C4=0.1551. As a first step PROMETHEE I and II, the Experts were asked to determine the Linguistic terms utilizing figure 6.2 and table 6.2 for evaluating each of the alternatives as shown in table 6.6. The linguistic terms are then converted into corresponding triangular fuzzy number presented in the table 7.7.

Table 6.6

Importance of the alternatives with respect to criteria assessed by Experts (linguistic variable)

Alternatives		Criteria			
		C1	**C2**	**C3**	**C4**
A1	E1	VH	VH	H	H
	E2	H	VH	L	VL
	E3	VH	VH	H	VH
	E4	H	H	VH	H
A2	E1	H	VH	L	H
	E2	EH	H	H	VH
	E3	VH	VH	H	VH
	E4	H	EH	VH	L
A3	E1	EH	VH	H	VH
	E2	H	VH	H	H
	E3	VH	L	L	VH
	E4	H	H	VH	H
A4	E1	H	H	L	H
	E2	H	VH	H	EH
	E3	VH	VH	VH	VH
	E4	H	H	EH	VH

In this step the converted TFN values of experts opinion (shown in table 6.7) are aggregated by using the Eq^{n} –(6.3) are presented in table 6.8.

Table 6.8

Aggregated Triangular fuzzy values of alternatives of each criteria

	C1			C2			C3			C4		
A1	(3.53,	6.12,	8.66)	(4.65,	7.28,	9.30)	(0.00,	4.65,	7.28)	(0.00,	0.0,	6.12)
A2	(3.91,	6.58,	8.66)	(3.91,	6.58,	8.66)	(0.00,	5.14,	7.82)	(0.00,	4.65,	7.28)
A3	(3.91,	6.58,	8.66)	(.00,0	5.14,	7.82)	(1.00,	4.65,	7.28)	(1.00,	6.12,	8.66)
A4	(2.97,	5.53,	8.05)	(3.53,	6.12,	8.66)	(0.00,	5.53,	7.82)	(0.00,	7.28,	9.30)

Table 6.7

Triangular fuzzy value of alternatives' linguistic evaluation

Alternative		C1	C2	C3	C4
A1	E1	(5.00, 7.50, 10.00)	(7.50, 10.00, 10.0)	(2.50, 5.00, 7.50)	(2.50, 5.00, 7.50)
	E2	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.00)	(0.00, 2.50, 5.00)	(0.00, 0.00, 2.50)
	E3	(5.00, 7.50, 10.00)	(5.00, 7.50, 10.00)	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.0)
	E4	(2.50, 5.00, 7.50)	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.0)	(2.50, 5.00, 7.50)
A2	E1	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.00)	(0.00, 2.50, 5.00)	(2.50, 5.00, 7.50)
	E2	(7.50, 10.00, 10.00)	(2.50, 5.00, 7.50)	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.0)
	E3	(5.00, 7.50, 10.00)	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.0)	(2.50, 5.00, 7.50)
	E4	(2.50, 5.00, 7.50)	(7.50, 10.00, 10.0)	(5.00, 7.50, 10.0)	(0.00, 2.50, 5.00)
A3	E1	(7.50,10.00,10.00)	(5.00, 7.50, 10.00)	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.0)
	E2	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.00)	(2.50, 5.00, 7.50)	(2.50, 5.00, 7.50)
	E3	(5.00, 7.50, 10.00)	(0.00, 2.50, 5.00)	(0, 2.50, 5.50)	(5.00, 7.50, 10.0)
	E4	(2.50, 5.00, 7.50)	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.0)	(2.50, 5.00, 7.50)
A4	E1	(2.50, 5.00, 7.50)	(2.50, 5.00, 7.50)	(0.00, 2.50, 5.00)	(2.50, 5.00, 7.50)
	E2	(2.50, 5.00, 7.50)	(5.00, 7.50, 10.0)	(2.50, 5.00, 7.50)	(7.50, 10.0, 10.0)
	E3	(5.00,7.50, 10.00)	(5.00, 7.50, 10.0)	(5.00, 7.50, 10.0)	(5.00, 7.50, 10.0)
	E4	(2.50, 5.00, 7.50)	(2.50, 5.00, 7.50)	(7.50, 10.0, 10.0)	(5.00, 7.50, 10.0)

The normalized Fuzzy decision matrix and weighted fuzzy decision matrix are calculated by using Eq^n-(6.5) and (6.7) respectively (shown in Table 6.9) and then de fuzzyfied by Eq^n-(6.7). (Presented in table 6.10). The preference between the pairs of alternatives is then calculated by using the "usual criterion" function presented in the Eq^n-(6.8) and is presented in the table 6.11.

Table 6.9

Weighted normalized fuzzy decision matrix

	C1			C2			C3			C4		
A1	(0.40,	0.70,	1)	(0.5,	0.78,	1)	(0,	0.59,	0.93)	(0,	0,	0.65)
A2	(0.45,	0.75,	1)	(0.42,	0.70,	0.93)	(0,	0.65,	1)	(0,	0.5,	0.78)
A3	(0.45,	0.75,	1)	(.,0	0.55,	0.84)	(0.12,	0.59,	0.93)	(0.10,	0.65,	0.93)
A4	(0.34,	0.63,	0.93)	(0.37,	0.65,	0.93)	(0,	0.70,	1)	(0	0.78,	1)

Table 6.10

Defuzzyfied fuzzy decision matrix

	C1	C2	C3	C4
A1	0.71	0.77	0.53	0.16
A2	0.74	0.69	0.58	0.45
A3	0.74	0.49	0.56	0.59
A4	0.64	0.66	0.60	0.64

Table 6.11

Pair wise preference function of the alternatives

	C1	C2	C3	C4
P(A1,A2)	0	1	0	0
P(A1,A3)	0	1	0	0
P(A1,A4)	1	1	0	0
P(A2,A1)	1	0	1	1
P(A2,A3)	0	1	1	0
P(A2,A4)	1	1	0	0
P(A3,A1)	1	0	1	1
P(A3,A2)	0	0	0	1
P(A3,A4)	1	0	0	0
P(A4,A1)	0	0	1	1
P(A4,A2)	0	0	1	1
P(A4,A3)	0	1	1	1

The weighted aggregated preference function is then calculated in this step by using Eq^n- (6.9), then the outgoing flow incoming flow and net flow are calculated by using Eq^n (6.10)-(6.12) result is presented in table 6.12

Table 6.12

Weighted aggregated preference function , outgoing, incoming, net flow and Ranking

	A1	A2	A3	A4	Q^+	Net flow	Ranking
A1		0.289	0.289	0.595	1.174	-0.653	**4**
A2	0.711		0.540	0.595	1.845	0.995	**1**
A3	0.711	0.155		0.305	1.171	-0.353	**3**
A4	0.405	0.405	0.695		1.506	0.011	**2**
Q^-	1.826	0.850	1.524	1.494			

The partial ranking of the alternatives is calculated by using Eq^n.-(6.12) via the fuzzy PROMETHEE I method. Basically, the greater the outgoing flow ($\emptyset^+$ value) and the smaller the incoming flow($\emptyset^-$ value) gives the better alternatives. Based on the partial ranking A2 outrank all other alternatives, A4 outrank A1 and A3 and A1 and A3 cannot be compared and A1 is the worst alternative. At the last complete ranking ($\emptyset^{net}$ value) is calculated by the fuzzy PROMETHEE II method by using Eq^n- (6.15) The greater the net flow ($\emptyset^{net}$ value) shows the better alternatives. As per to this value, the complete ranking can be obtained

A2 is determined to be the best alternative, and A4, the worst alternative by PROMETHEE II as shown in (Figure 6.7). While in PROMETHEE I, A2 outrank all other and A1 is worst alternatives. According to PROMETHEE II A4 is better than A1 and A3, A1 is the worst alternatives. Fuzzy PROMETHEE I and fuzzy PROMETHEE II give the same result in both the partial and complete ranking. (Shown in Figure 6.7)

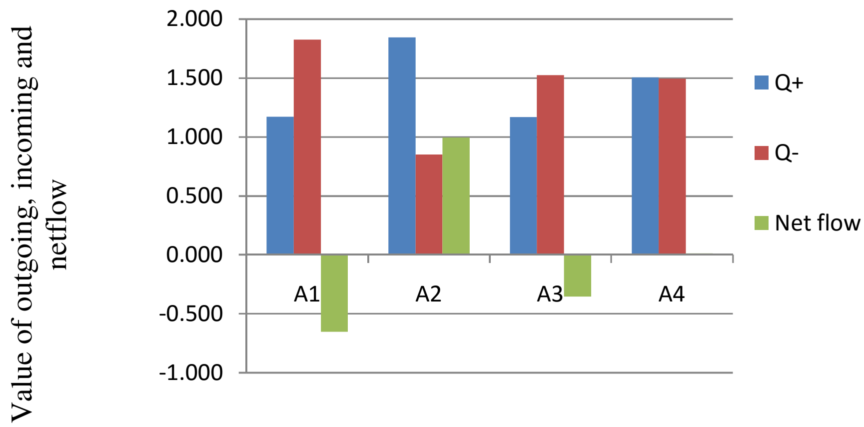


Figure 6.7 Fuzzy PROMETHEE I-II partial and complete rankings

6.4. COMPARISION AMONG MCDM METHOD

6.4.1 Fuzzy TOPSIS

The TOPSIS was created by Hwang and Yoon (1981) to decide the best option dependent on the ideas of the compromise solution (Celik et al., 2012; Peng, 2012). The compromise solution can be viewed as picking the solution with the shortest distance from the Fuzzy Positive Ideal Solution (FPIS) and the most distant from the Fuzzy Negative Ideal Solution (FNIS). Since the favored evaluations as a rule allude to the subjective uncertainty, it is normal to extent TOPSIS to consider the circumstance of fuzzy numbers (Tzeng and Huang, 2011)

The alternatives are assessed and in this way chose by ranking their relative closeness joining two distance measures. The numerical model utilized above is applied in TOPSIS to analyze the ranking of the methods.

The numerical model uses similar criteria, number of Experts and alternatives as utilized in PROMETHEE. Be that as it may, the TOPSIS method and the technique in turning out with the ranking of the alternatives are very extraordinary. The same criterion weights calculated by Fuzzy AHP value C1= 0.3052, C2=0.2895, C3=0.2503, C4=0.1551 are also consider in TOPSIS method.

The Fuzzy Positive Ideal Solution (FPIS) and the Fuzzy Negative Ideal Solution (FNIS) are determined by using Eq^n- (6.16)

$$\text{FPIS } (F^*) = (\tilde{v}^*{}_1, \tilde{v}^*{}_2\, \tilde{v}^*{}_3, \dots, \tilde{v}^*{}_n) \text{ and FNIS } (F^-) = (\tilde{v}^-{}_1, \tilde{v}^-{}_2\, \tilde{v}^-{}_3, \dots, \tilde{v}^-{}_n) \qquad (6.16)$$

Where $\tilde{v}^*{}_j = \max_i \{v_{ij3}\}$ and $\tilde{v}^-{}_j = \min_i \{v_{ij1}\}$; i=1, 2, …, m; j=1, 2, …,n

Now, FPIS and Fuzzy negative ideal solution (FNIS) are calculated as in the following

F*= (0.305, 0.305, 0.305) (0.289, 0.289, 0.289) (0.250, 0.250, 0.250) (0.155, 0.155, 0.155)

F-= (0.105, 0.105, 0.105) (0.000, 0.000, 0.000) (0.000, 0.000, 0.000) (0.000, 0.000, 0.000)

Then the distance d_v of each Alternatives from FPIN (F*) and FNIS (F^-) are computed by using Eqn.(6.17) and (6.18). As follows:

$$\tilde{d}^*{}_i = \sum_{j=1}^{n} d_v\left(\tilde{v}^*{}_{ij}, \tilde{v}^*{}_j\right); i = 1, 2, \dots, m \qquad (6.17)$$

$$\tilde{d}^-{}_i = \sum_{j=1}^{n} d_v\left(\tilde{v}^-{}_{ij}, \tilde{v}^-{}_j\right); i = 1, 2, \dots, m \qquad (6.18)$$

Where d_v is the distance measurement between two Fuzzy numbers.

The distance $\tilde{d}^*{}_i$ and $\tilde{d}^-{}_i$ of A_i (i=1, 2, 3,4) alternative from FPIS and FNIS are calculated as above and the result is stated in the Tables 6.13 and 6.14.

Table 6.13

Distances between Ai(i=1,2,3,4) and F* with respect to criterion

d(A1,F*)=	0.137	0.105	0.177	0.187
d(A2,F*)=	0.121	0.130	0.168	0.123
d(A3,F*)=	0.121	0.216	0.163	0.097
d(A4,F*)=	0.161	0.145	0.162	0.096

Table 6.14

Distances between Ai(i=1,2,3,4) and F- with respect to criterion

d(A1, F-)	0.229	0.376	0.277	0.102
d(A2, F-)	0.238	0.345	0.300	0.144
d(A3, F-)	0.238	0.291	0.27	0.177
d(A4, F-)	0.200	0.336	0.306	0.197

$$CC_i = \frac{d^-{}_i}{d^-{}_i - d^*{}_i}, i = 1, 2, \dots, m \quad (6.19)$$

Based on the fuzzy positive ideal solution (FPIS) (F*) and fuzzy negative ideal solution(FNIS) (F^-) the table 6.15 represented the distance measurement including the associated ranks of all the alternatives.

Based on the result in the table 6.15, alternatives A2 is ranked highest followed by A4 and A3 respectively.

Table 6.15

Closeness coefficient (CC_i) of alternatives and their final ranking

	Alternatives	$\tilde{d}^*{}_i$	$\tilde{d}^-{}_i$	$\tilde{d}^*{}_i + \tilde{d}^-{}_i$	$CC_i = \frac{\tilde{d}^-{}_i}{\tilde{d}^*{}_i + \tilde{d}^-{}_i}$	Rank
A1	Dams and reservoirs	0.606	0.986	1.592	0.619	4
A2	Levees and floodwalls:	0.543	1.027	1.570	0.654	1
A3	Channel Improvement / dredging:	0.597	0.984	1.580	0.622	3
A4	Flood diversion	0.564	1.040	1.604	0.649	2

6.4.2 Fuzzy VIKOR:

The VIKOR method was created by Opricovic (1998) to take care of MCDM issues with clashing and non-commensurable criteria (Gul et al., 2016; Opricovic and Tzeng, 2004). It is utilized to decide a positioning request from a lot of alternatives, the compromise solution for an issue with clashing criteria, and to decide the weight solidness interims for preference stability of the compromise solution acquired with the given weights (Opricovic an Tzeng, 2007). The VIKOR technique decides a compromise solution that gives the greatest group utility to the majority and at least individual regret for the opponent. The compromise positioning can be gotten by contrasting the proportion of closeness with the perfect option in the VIKOR technique. The fuzzy VIKOR technique is proposed to take care of fuzzy multi criteria issue with clashing and non-commensurable criteria. The method manages problems considering the two criteria and weights that could be fuzzy sets (Opricovic, 2011).

Accepting the same number of criteria, number of decision makers, alternatives and fuzzy linguistic terms, a numerical example is consider below for the comparison with the fuzzy PROMETHEE and fuzzy TOPSIS results.

The fuzzy best value (FBV, $\tilde{f}_j^*$) and fuzzy worst value (FWV, $\tilde{f}_j^-$) are determined based on the aggregated fuzzy decision matrix (shown in table 6.8) by using eq. (6.20) are shown in table 6.16.

$$\tilde{f}_j^* = max\tilde{f}_{ij} ,\forall\, i \quad \tilde{f}_j^- = min\tilde{f}_{ij}, \forall\, i \qquad (6.20)$$

Table 6.16

Fuzzy Best Value and Fuzzy Worst Value

$\tilde{f}_1^*$	3.913	6.580	8.660	$\tilde{f}_1^-$	2.973	5.533	8.059
$\tilde{f}_2^*$	4.653	7.282	9.306	$\tilde{f}_2^-$	0.000	5.149	7.825
$\tilde{f}_3^*$	1.000	5.533	7.825	$\tilde{f}_3^-$	0.000	4.653	7.330
$\tilde{f}_4^*$	1.000	7.282	9.306	$\tilde{f}_4^-$	0.000	0.000	6.124

The normalized fuzzy distance is calculated by using eq. (6.21), the result is shown in the table 6.17 and the criterion weight determined by Fuzzy AHP is also shown in the last column of table 6.17

The normalized fuzzy distance d_{ij}, i=1,2,m, j=1,2,...n

$$d_{ij} = \frac{d(\tilde{f}_j^* - \tilde{f}_{ij})}{d(\tilde{f}_j^* - \tilde{f}_j^-)} \qquad (6.21)$$

Table 6.17

Normalized fuzzy distances for the four alternatives

	Alternatives				
	A1	A2	A3	A4	Criteria Wt
C1	0.387	0	0	1	0.305
C2	0	0.226	1	0.325	0.289
C3	0.999	0.753	0.727	0.703	0.250
C4	1	0.432	0.165	0.124	0.155

The values S_i, R_i and Q_i, i = 1, 2. . . m are calculated by Eqs. (6.22)– (6.23) and the results are shown in table 6.18

$$S_i = \sum_{j=1}^{n} w_j * d_{ij} \tag{6.22}$$

$$R_i = \max_{j} \left(w_j * d_{ij}\right) \tag{6.23}$$

Where w_j are the important weights of criteria obtained by using Fuzzy AHP.

$$Q_i = \frac{V(S_i - S^*)}{(S^- - S^*)} + \frac{(1-v)(R_i - R^*)}{(R^- - R^*)} \tag{6.24}$$

Where $S^* = Min\, S_i$, $S^- = Max\, S_i$, $R^* = Min\, R_i$, $R^- = Max\, R_i$ and v is introduced as a weight for the strategy of maximum group utility, whereas $(1 - v)$ is the weight of the individual regret. The value of v is set to 0.5 in this study

The rankings of the four alternative methods by S, R and Q in increasing order are shown in table 6.19

Using fuzzy PROMETHEE, we consider the type 1 (usual criterion) preference function to evaluate the ranking of the flood control project selection alternatives.

Table 6.18

The values of S, R and Q for all alternatives

	Alternatives			
	A1	A2	A3	A4
S	0.118	0	0	0.305
R	0.250	0.188	0.289	0.305
Q	0.458	0	0.432	1

Table 6.19

The rankings of the four alternative by S, R and Q

	Alternatives			
	A1	A2	A3	A4
S	3	1	1	4
R	3	1	2	4
Q	3	1	2	4

Table 6.20

Ranking of alternatives based on Fuzzy PROMETHEE, fuzzy TOPSIS and fuzzy VIKOR

	Fuzzy PROMETHEE		Fuzzy TOPSIS		Fuzzy VIKOR (v=0.5)	
Alternatives	Net Flow	Rank	CC value	Rank	Q Value	Rank
A1	-0.653	4	0.619	4	0.458	3
A2	0.995	1	0.654	1	0.000	1
A3	-0.353	3	0.622	3	0.433	2
A4	0.011	2	0.649	2	1.000	4

In this study the comparison of three methods fuzzy PROMETHEE, fuzzy TOPSIS and fuzzy VIKOR are summarized in table 6.20.

The alternative ranking obtained from the usual criterion preference function gives the same result as the fuzzy TOPSIS and fuzzy VIKOR method. In these approaches, A2 is determined as the best alternatives. In this study greater net flow value shows a higher- ranking order in fuzzy PROMETHEE, greater closeness coefficient (CC_i) higher the alternative ranking I fuzzy TOPSIS, this is vice versa in fuzzy VIKOR. In fuzzy VIKOR a greater index value shows a lower ranking order.

6.5 SENSITIVITY ANALYSIS

This section of the chapter analyses the cross impact of affected choice on the alternatives rating by the four criteria on changing weights.

According to the outcomes that got with PROMETHEE I, A1 and A3 can't be compared. The explanation of this circumstance is that, A3 is better than A1 in the outgoing flow, at the same time, A1 is prevalent superior to A3 in the incoming flow. To look at these two alternatives, the net flow ought to be determined in PROMETHEE II and with PROMETHEE II's complete ranking; it finds that A3 is better than A1.

As mentioned previously, the weight of the choice criteria are decided by means of F-AHP. In this stage, the sensitivity of the outcomes to the adjustments in the criteria weight is analyzed. The weights of criterion are (C1= 0.3052, C2=0.2895, C3=0.2503, C4=0.1551). As an example (as case -1) for rating the four alternatives criterion weights of C1 and C2 are increasing by 0.1 and decreasing the weights of C3 and C4 by 0.1 respectively. The criterion weights become (C1= 0.4052, C2=0.3895, C3=0.1503, C4=0.0551)

(As case-2) criterion weights of C1 and C2 are decreasing by 0.1 and increasing the weights of C3 and C4 by 0.1 respectively. The criterion weights become (C1= 0.2052, C2=0.1895, C3=0.3503, C4=0.2551)
Keeping all the experts' opinion as given in table 6.6 and using the criterion weights as per case-1 and case-2 the rating of the alternatives of fuzzy PROMETHEE, fuzzy TOPSIS and fuzzy VIKOR are shown in table 6.21.

Table 6. 21

Comparative Ranking

	Original Ranking			Case-1 Ranking			Case-2 Ranking		
Alternatives	F PROMETHEE	FTOPSIS	F VIKOR	F PROMETHEE	F TOPSIS	FVIKOR	F PROMETHEE	FTOPSIS	FVIKOR
A1	**4**	**4**	**3**	**2**	**2**	**2**	**4**	**4**	**4**
A2	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**2**
A3	**3**	**3**	**2**	**3**	**4**	**3**	**3**	**3**	**1**
A4	**2**	**2**	**4**	**4**	**3**	**4**	**1**	**2**	**3**

6.6 **CONCLUSION**

In this chapter a model for assessing and choosing among various flood control project has been proposed. Flood control project is an unpredictable issue which both subjective and quantitative qualities must be considered. Since subjective criteria make the assessment procedure hard and vague, it is reasonable and adaptable to express the judgments of experts in fuzzy number. This study we proposes a fuzzy AHP and fuzzy PROMETHEE method based on triangular fuzzy interval numbers with respect to preference functions (usual criterion) for selection of flood control alternative. As a result fuzzy AHP determined economic factor (C1) and technical factor (C2) are the most important and 2^{nd} most important criteria respectively as it has highest and 2^{nd} highest weight priority.

As to of this fuzzy PROMETHEE based model, the consequence of the proposed method is compared with three diverse fuzzy MCDM methods (fuzzy PROMETHEE, fuzzy VIKOR, and fuzzy TOPSIS). Likewise, the connections between the analyzed methods and the proposed situations for fuzzy PROMETHEE are assessed. The goal is to choose the most suitable flood control elective. The fundamental preferences of the methodology are thought of the vagueness, uncertainty, and fuzziness to decision making environment. The method proposed here is demonstrated to be a feasible and efficient tool for flood control alternative determination when the right preference function is selected by the decision-makers.

Regardless of the distinctions in decision makers' assessment, the fuzzy PROMETHEE, fuzzy TOPSIS and fuzzy VIKOR method presumes that A2-Levees and floodwalls is the most ideal approach to relieve or control floods. The outcome might be helpful to the administration especially in settling flood event where floods are considered as one of the most continuous natural fiascos in this region. However, the stability of the results has yet to be explored and subjected to further investigation. Further work needs to be carried out to establish the stability of the final ranking. Future studies on the current topic are also suggested in validating the results using other MCDM methods