Chapter- 5

STRUCTURAL FLOOD CONTROL MODELLING

AHP and Fuzzy VIKOR Approach modelling for flood control project selection

Some content of this chapter is published in UGC Listed Journal "International Journal of Applied Engineering Research" ISSN 0973-4562 Volume 14, Number 17 (2019) pp. 3579-35889 © Research India Publications. http://www.ripublication.com

Some of paper is presented in the National Seminar on "Advances in Mathematical Sciences" (22 December, 2018) (Celebrating National Mathematics Day and 131st Birth Anniversary of Srinivasa Ramanujan) Organized by Department of Mathematics, Gauhati University, Guwahati-781014, Assam

5.1 INTRODUCTION:

In this chapter we proposed flood control project that data are measured based on data collected via questionnaires from the experts in triangular fuzzy number form. In this proposed methodology, the decision- makers' opinions on the weighting of criteria are determined by a fuzzy AHP procedure. The ranking value at the aggregating part is determined by Fuzzy VIKOR method.

Flood control or flood relief measure can be sorted into two groups. The first group, the structural measures, which includes common works in the flood plain as well as the catchment, and incorporates development of dams, repositories, hindering bowls and levee banks; channel changes; flood-sealing of properties; catchment alterations; and plans of seepage and flood security works. The subsequent group, the non-auxiliary measures, incorporates flood anticipating, flood cautioning and crisis arranging, arranging controls and obtaining of flood inclined territories inside the catchment, and giving flood protection to influenced individuals Gershon et al. (1983).

Multi criteria decision making (MCDM) technique have been developed and applied to various flood control planning and studies in river basin (Gershon et al. (1983); Willett et al. (1991); Ko et al. (1994); Pillai et al. (1995)). Raju and Pillai in (1999) have made a comparison of five MCDM methods, namely, ELECTRE-2, PROMETHEE-2, AHP, CP and EXPROM-2 to select the best reservoir configuration for the case study of Chaliyar river basin, Kerala, India. Chen et al. (2004) established a multi criteria fuzzy recognition model for flood operations. A subjective preference and iterative weight method is proposed for weight assessment. Carlos A et al. (2004), proposed MCDM method, The MACBETH approach – Measuring Attractiveness by a Categorical Based Evaluation Technique – was then used to study Livramento creek in the peninsula of Setúbal, in Portugal. Ahmad et al. (2000) presented System dynamics, a feedback-based object-oriented simulation approach is presented for modeling reservoir operations. The proposed approach is applied to the Shellmouth reservoir on the Assiniboine River in Canada

Opricovic in (1998 &2007) devolved the VIKOR method to solve multi criteria decision making problem with conflicting and non-commensurable criteria. This method is based on an aggregating function representing “closeness to the idea” which originated in compromising programming method Opricovic and Tzeng (2004); Opricovic (2007). The VIKOR method of compromise ranking determines a compromise set providing maximum group utility for the “majority” and minimum of an individual regrets for the “opponent” Opricovic and Tzeng (2000). On the other hand some researchers have evaluated VIKOR method under Fuzzy environment, For example, Fuzzy VIKOR in water resources planning Opricovic (2011). Fuzzy VIKOR for environmental assessment Kim et al. (2015) and Kim et al. (2013a). Chang et al. (2009) and (2011) employed modified VIKOR method to assess the Tseng-Wen reservoir watershed in southern Taiwan to classify land use according to its environmental characteristics.

Reviewing different studies on flood control operation the MCDM method in the selection process have the great applicability. According to Akter T. et al. (2002) flood management decision making problem often involve multiple objectives and multiple stakeholders. To enable more effective and acceptable decision outcomes uncertainty plays an important role in flood management decision making process. In (1975) Zadeh and Buckley (1985) have introduced a fuzzy set concept that are more reliable to handle all the uncertainty. Most of the earlier paper Chen et al. (2004); Carlos et al. (2004) and Ahmed et al. (2000) of flood control project used only the qualitative and quantitative data in fuzzy number form.

The rest of the chapter is organized as follows: in section 5.2, we study about the flood control alternatives and selection of criteria in flood management control project. In section 5.3 We applied the proposed framework for the case of Aie river basin of Chirang District, BTAD, Assam, India, and finally conclusion have been drawn in section 5.4.

5.2 FLOOD CONTROL PROJECT ALTERNATIVES:

The main objective of flood control planning is to reduce the flood damage in a minimum constant with the cost involved. The flood control alternatives can be classified into two groups: structural and non structural. Structural alternatives represent traditional flood damage reduction by physical means (Zamri et al. 2013) In other words, the construction of flood control facilities can be referred as structural alternatives.

5.2.1 The structural alternatives of flood damages measure are as (Zamri et al. 2013)

Table 5.1

Alternatives	Description
A1–Dams and Reservoirs	Flood control dams/reservoirs may be constructed across the upper stream of the river to store flood water s and the magnitude of the flood water can be reduced the downstream stage of the flood. The store water can be used to generate the electricity and agricultural purposes.
A2 – Embankment and side Bands	It is the oldest commonly used methods of protection against the floods. Embankments are constructed parallel to the rivers to prevent overflows of flood water to the flood plain.
A3 –De-silting and dredging	De-silting and dredging of river is also useful method that improves the hydraulic capacity of channel can lower the water stage and increase the carrying capacity of water.
A4 – Channel diversion	An artificial channel can be used to divert the flood water that can increase the flood discharge and can reduce the damage.

5.2.2 Identification of decision making criterion:

The project selection process is usually difficult and it involves huge investment for implementation. The impact on environment and social also very high and may be as high as the cost of implementation of project (Zamri et al. 2013) So considering different angles the selection of flood control project must be considered in most favorable solution.

In order to evaluate the alternatives, four criteria and 12 sub- criteria are developed (Zamri et al. 2013), is shown in table 5.2

Table 5.2

Four main criteria and 12 sub- criteria as developed by Zamri et al. 2013

Main Criteria	Sub-criteria	Related literature source
Ec: Economic	Ec1: Cost of Project	(Willet, 19910:Zamri et al. 2013)
	Ec2: Implementation and maintenance	(Zamri et al. 2013)
	Ec3: Benefit of Project	(Willet, 19910:Zamri et al. 2013)
Sc: Social	Sc1: Effect on social fabric	(Carlos, 2004), (Zamri et al. 2013)
	Sc2: Perception of flood	(Carlos, 2004)
	Sc3: Recreation	(Zamri et al. 2013)
Ev: Environmental	Ev1: Ecological Restoration	(Carlos, 2004), (Zamri et al. 2013)
	Ev2: Land Erosion	(Carlos, 2004), (Zamri et al. 2013)
	Ev3: Water Quality	
Tc: Technical	Tc1: Complexity of implementation	(Zamri et al. 2013)
	Tc2: Level of protection	(Zamri et al. 2013)
	Tc3: Complexity of maintenances	(Zamri et al. 2013)

5.3 APPLICATIONSOF PROPOSED FRAMWORK

5.3.1 CASE STUDY

Aie Manas River which is originates in the Black Mountains of Bhutan at the altitude about 4,915 meters near the village of Bangpari, is about 110km in length passes through Chirang District, BTAD (Bodoland Territorial Area District), (in Fig.3) Assam. These river falls under the Manas-Beki-Aie sub basin. It is one of the biggest and important sub basin of Brahmaputra river basins. The sub basin lies between altitude 26° 15N and 28° 40N and longitude 90° 13’E and 92° 18’E. The entire course of Aie has been experiencing the natural process of self adjustment of its section of parameters. The maximum average rain fall is about 2448.8mm annually [48]. The highest temperature recorded in the area is 35.30°c and minimum is 8.20°c. For the last ten years about 1270 numbers of houses has been damaged due to the erosion and some parts of village has been displaced (2013-14) as per the report from District Disaster Management Report.

This historical flash floods alarming Aie river have shown that structural flood control measure are required to protect natural resources, agriculture land and villages from flood risk and land erosion.

Figure 5.1 (map) Satellite map of Chirang District Source: Google earth

5.3.2 Priority weight for decision criteria by (FAHP)

According to proposed model, the main objective of using Fuzzy AHP is to determine important weight of the criteria that will be used in Fuzzy VIKOR method (Chang, 2011). According to the proposed model the weights of the Criteria and sub criteria can be analyzed (shown in Table 5.2). A panel of three experts (Decision Makers) was selected to find the weights of criteria. They are DM1-Project Director (District Disaster Management), DM2- Executive Engineer Irrigation Department and DM3- Assistant Project Director (District Disaster Management) The computational procedure for determining the weights is as follows.

Step-1: The experts were asked to give the rate pair wise comparisons to each criteria identified in table 5.2 according to the linguistic variable as per table 5.3 and the rating obtained are presented in the table 5.4.

Step-2: The linguistic variable are converted to the corresponding Triangular Fuzzy Numbers (TFNs) and aggregating the elements of synthetic pairwise comparison matrix by using Geometric mean method suggested by (Lee 2009) (Eq-(5.1) that is: shown in table 5.5

$$l_{ij} = \left(\prod_{p=1}^{p} l_{ijp}\right)^{1/p}, m_{ij} = \left(\prod_{p=1}^{p} m_{ijp}\right)^{1/p},$$

$$u_{ij} = \left(\prod_{p=1}^{p} u_{ijp}\right)^{1/p} \tag{5.1}$$

(Due to the space limitation, linguistic evaluation matrix and fuzzy evaluation matrix of main criteria only are given here.)

Step 3: Likewise, Fuzzy geometric mean of pairwise comparison matrix of sub criterion are computed and then Important weights that is priority vector crisp relative for identified criteria is obtained from the calculation based on pairwise comparison matrixes by using eq. (2.2) to eq. (2.7), the extent analysis method proposed by Chang (1996) and values are presented in the table 5.6. We are using this criterion weight for ranking the alternatives in fuzzy VIKOR method

Table 5.3

Linguistic variables for Fuzzy Pairwise Scale

Linguistic Scale	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal Scale
Equal Important(EI)	(1, 1, 1)	(1, 1, 1)
Less Important (LI)	(2/3, 1, 3/2)	(2/3, 1, 2/3)
Fairly Important (FI)	(3/2, 2, 5/2)	2/5, ½, 2/3)
Very Important (VI)	5/2, 3, 7/2)	(2/7, 1/3, 2/5)
Absolute Important(AI)	(7/2, 4, 9/2)	(2/9, ¼, 2/7)

Table 5.4

Pairwise comparison of Main criteria via Linguistic variables.

		Ec	Sc	Ev	Tc
Ec	DM1	EI	LI	FI	VI
	DM2	EI	FI	VI	EI
	DM3	EI	EI	EI	LI
Sc	DM1		EI	LI	LI
	DM2		EI	EI	EI
	DM3		EI	FI	FI
Ev	DM1			EI	LI
	DM2			EI	FI
	DM3			EI	VI
Tc	DM1				EI
	DM2				EI
	DM3				EI

Table 5.5

Fuzzy geometric mean of pairwise comparison (Main Criteria)

	Ec	Sc	Ev	Tc
Ec	(1,1,1)	(1,1.26,1.554)	(1.554,1.817,2.061)	(1.186,1.442,1.738)
Sc	0.644,0.794,1	(1,1,1)	(1,1.260,1.554)	(1,1.260,1.554)
Ev	(0.485,0.550,0.644)	(0.644,0.794,1)	(1,1,1)	(1.357,1.817,2.359)
Tc	(0.575,0.693,0.843)	(0.644,0.794,1)	(0.424,0.550,0.737)	(1,1,1)

Table 5.6

Final priority weights of Main criteria and Sub criteria

Main Criteria	Weights (w_i)	Sub Criteria	Weight (wij)	Final weights (W=wixwij)
Ec: Economic	0.3037	Ec1	0.4404	0.1337
		Ec2	0.3667	0.1114
		Ec3	0.1930	0.0586
Sc: Social	0.2884	Sc1	0.4783	0.1379
		Sc2	0.3108	0.0896
		Sc3	0.2109	0.0608
Ev: Environmental	0.2373	Ev1	0.4610	0.1094
		Ev2:	0.3965	0.0941
		Ev3:	0.1425	0.0338
Tc: Technical	0.1707	Tc1:	0.4165	0.0711
		Tc2:	0.4239	0.0724
		Tc3:	0.1506	0.0257

5.3.3 Application of Fuzzy VIKOR for ranking Alternatives

This step fuzzy VIKOR method is applied for the selection of best structural flood control project as the alternatives shown in the (table 5.1). The evaluation main criteria and sub-criteria shown in Table 5.2. There are four main criteria and twelve sub criterions are considered in this study.

First of all a committee of three experts has been identified they are E1-Project Director (District Disaster Management), E2- Executive Engineer Irrigation Department E3- Assistant Project Director (District Disaster Management)

We utilized the fuzzy-VIKOR method to determine the best flood control project alternatives consists of the following steps.

Step 1: The three decision makers uses the linguistic variable defines the table 5.7 to evaluate the alternatives with respect to criterion are presented in table 5,8.

Table 5.7

Linguistic variables for the rating of Alternatives

Linguistic variable	Triangular Fuzzy Number
Best or Very High (B)	(8,9,10)
Good or High (G)	(6, 7, 8)
Fair or Medium (F)	(4, 5,6)
Poor or Low (P)	(2, 3, 4)
Worst or very low (W)	(1, 1, 2)

Table 5. 8

Linguistic assessment of alternatives given by three experts

Experts	Alternatives	Criteria									
		Ec1	Ec2	Ec3	Sc1	Sc2	Sc3	Ev1	Ev2	Ev3	Tc1
E1	A1	B	F	F	G	G	B	F	F	G	B
	A2	B	F	G	F	P	G	F	F	G	G
	A3	G	P	G	B	P	P	G	F	G	F
	A4	B	G	P	G	F	F	B	F	B	B
E2	A1	B	F	F	B	P	B	P	P	G	G
	A2	B	P	P	P	B	L	P	P	F	G
	A3	B	G	G	F	G	P	F	G	F	P
	A4	P	F	P	G	F	P	F	F	F	F
E3	A1	B	G	F	F	P	B	G	F	B	P
	A2	G	F	P	G	F	F	F	G	G	F
	A3	B	P	G	F	F	P	F	P	G	F
	A4	G	F	B	F	P	G	B	P	G	F

Step 2: The linguistic evaluation shown in table 5.7 are then converted into triangular fuzzy number and then the aggregated fuzzy rating of alternatives are calculated by using eq.-(5.1) to construct fuzzy decision matrix, as shown in table 5.9.

Table 5. 9 ,

Aggregated fuzzy ratings of alternatives and aggregated fuzzy weights of criteria.

Criteria	Alternatives			
	A1	A2	A3	A3
Ec1	(8.00, 9.00, 10.00)	(7.33, 8.33, 9.33)	(7.33, 8.33, 9.33)	(5.33, 6.33, 7.33)
Ec2	(4.66, 5.66, 6.66)	(3.33, 4.33, 5.33)	(3.33, 4.33, 5.33)	(4.66, 5.66, 6.66)
Ec3	(4.00, 5.00, 6.00)	(3.33, 4.33, 5.33)	(6.00, 7.00, 8.00)	(4.00, 5.00, 6.00)
Sc1	(4.66, 5.66, 6.66)	(4.00, 5.00, 6.00)	(5.33, 6.33, 7.33)	(5.33, 6.33, 7.33)
Sc2	(3.33, 4.33, 5.33)	(3.33, 4.33, 5.33)	(4.33, 5.33, 6.33)	(3.33, 4.33, 5.33)
Sc3	(8.00, 9.00, 10.00)	(4.00, 5.00, 6.00)	(2.00, 3.00, 4.00)	(4.00, 5.00, 6.00)
Ev1	(4.00, 5.00, 6.00)	(3.33, 4.33, 5.33)	(4.66, 5.66, 6.66)	(6.66, 7.66, 8.66)
Ev2	(3.33, 4.33, 5.33)	(4.00, 5.00, 6.00)	(4.00, 5.00, 6.00)	(3.33, 4.33, 5.33)
Ev3	(6.66, 7.66, 8.66)	(5.33, 6.33, 7.33)	(5.33, 6.33, 7.33)	(4.00, 5.00, 6.00)
Tc1	(3.33, 4.33, 5.33)	(5.33, 6.33, 7.33)	(3.33, 4.33, 5.33)	(5.33, 6.33, 7.33)
Tc2	(1.33, 1.66, 2.66)	(3.00, 3.66, 4.66)	(3.33, 4.33, 5.33)	(5.33, 6.33, 7.33)
Tc3	(2.66, 3.66, 4.66)	(2.66, 3.66, 4.66)	(5.33, 6.33, 7.33)	(2.66, 3.66, 4.66)

Step 3: The fuzzy best value (FBV) and fuzzy worst value (FWV) are determined using eq. (2.11) are shown in table 5.10.

Table 5.10

The fuzzy best and fuzzy worst values of all criteria ratings

f^*_1	(8.00,	9.00,	10.00)	f^-_1	(5.33,	6.33,	7.33)
f^*_2	(4.67,	5.67,	6.67)	f^-_2	(3.33,	4.33,	5.33)
f^*_3	(6.00,	7.00,	8.00)	f^-_3	(3.33,	4.33,	5.33)
f^*_4	(5.33,	6.33,	7.33)	f^-_4	(4.00,	5.00,	6.00)
f^*_5	(4.33,	5.33,	6.33)	f^-_5	(3.33,	4.33,	5.33)
f^*_6	(8.00,	9.00,	10.00)	f^-_6	(2.00,	3.00,	4.00)
f^*_7	(6.67,	7.67,	8.67)	f^-_7	(3.33,	4.33,	5.33)
f^*_8	(4.00,	5.00,	6.00)	f^-_8	(3.33,	4.33,	5.33)
f^*_9	(6.67,	7.67,	8.67)	f^-_9	(4.00,	5.00,	6.00)
f^*_{10}	(5.33,	6.33,	7.33)	f^-_{10}	(3.33,	4.33,	5.33)
f^*_{11}	(5.33,	6.33,	7.33)	f^-_{11}	(1.33,	1.67,	2.67)
f^*_{12}	(5.33,	6.33,	7.33)	f^-_{12}	(2.67,	3.67,	4.67)

Step 4: The normalized fuzzy distance is determined by using eq. (2.12) are shown in the table 5.10 and the criterion weight determined by Fuzzy AHP is also shown in the last column of table 5.11.

Table 5.11

Normalized fuzzy distances for the four alternatives and Criterion Weight

Criteria	Alternatives				
	A1	A2	A3	A4	Weight
Ec1	0.00	0.25	0.25	1.00	**0.4404**
Ec2	0.00	1.00	1.00	0.00	**0.3667**
Ec3	0.75	1.00	0.00	0.75	**0.1930**
Sc1	0.50	1.00	0.00	0.00	**0.4783**
Sc2	1.00	1.00	0.00	1.00	**0.3108**
Sc3	0.00	0.67	1.00	0.67	**0.2109**
Ev1	0.80	1.00	0.60	0.00	**0.4610**
Ev2	1.00	0.00	0.00	1.00	**0.3965**
Ev3	0.00	0.50	0.50	1.00	**0.1425**
Tc1	1.00	0.00	1.00	0.00	**0.4165**
Tc2	1.00	0.57	0.45	0.00	**0.4239**
Tc3	1.00	1.00	0.00	1.00	**0.1506**

Step 5: The values S_i, R_i and Q_i, i = 1, 2, . . . , m are calculated by Eqs. (2.13)–(2.15) And the results are shown in table 5.12

Table 5.12

The values of S, R and Q for all alternatives.

Alternatives				
	A1	**A2**	**A3**	**A4**
S	2.4510	2.5259	1.6423	1.7262
R	0.4239	0.5000	0.5000	1.0000
Q	0.4576	0.5660	0.0660	0.5474

Step 6: The rankings of the four alternative methods by S, R and Q in increasing order are shown in table 5.13

Table 5.13

The rankings of the four alternatives by S, R and Q in increasing order.

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

Step 10: As we see in Table 5.14, the treatment alternative A3 is apparently the best flood control project alternatives in accordance with the values of Q. Also the conditions C1 and C2 are satisfied by

When v=0.5

Q (A1)-Q (A2) = 0.4576-0.0660=0.3916>1/ (4-1)

and A3 is best ranked by S.

Thus, **A3 –De-silting and dredging** is the most suitable structural flood control model followed by A1

Table 5.14

The Q for different values of v

	Alternatives			
	A1	A2	A3	A4
v=0.10	0.092	0.219	0.119	0.909
v=0.50	0.458	0.566	0.066	0.547
v=0.75	0.686	0.783	0.033	0.321
v=0.90	0.824	0.913	0.013	0.185

The ranking of Q for different value (v=0.1, 0.5, 0.75, 0.9) are shown in the Table 5.15 and graph in figure 5.4

Table 5.15

Ranking of alternatives by Q for different values of v

	Alternatives			
	A1	A2	A3	A4
v=0.10	1	3	2	4
v=0.50	2	4	1	3
v=0.75	3	4	1	2
v=0.90	3	4	1	2

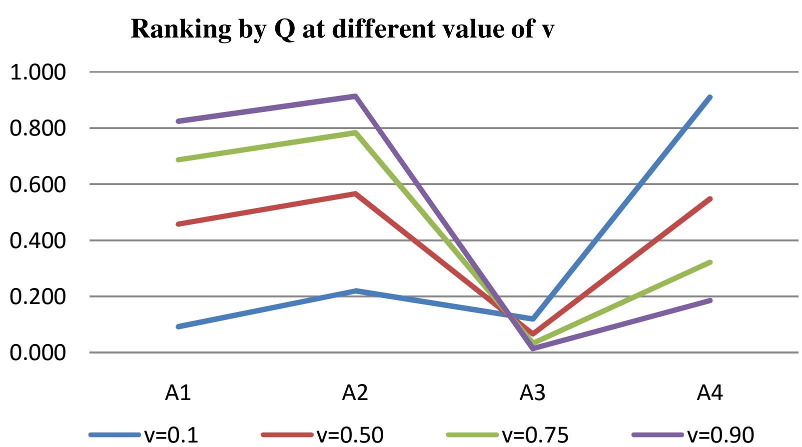

Figure 5.2

5.4 CONCLUSION

The fuzzy VIKOR method focuses on ranking and selecting from a set of alternatives in a fuzzy environment. Due to its characteristics and capabilities, the fuzzy VIKOR method has been widely studied and applied in flood risk management problems. The fuzzy VIKOR method is based on aggregating fuzzy measure Q that represents the distance of an alternative to the ideal solution. In this research, we combine fuzzy VIKOR and fuzzy AHP approach to develop a more accurate flood control project selection methodology. A numerical example illustrates an application of fuzzy VIKOR method. It is an intention to demonstrate the conceptual and operational justification of the application of the method in real world problem.