**A STUDY ON FUZZY APPROACH FOR FLOOD RISK MANAGEMENT IN BTAD AREA**

A Thesis

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**Chapter -1**

**GENERAL INTRODUCTION**

* 1. **INTRODUCTION**

### LITERATURE SURVEY

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* 1. **INTRODUCTION:**

Flood is a cataclysmic event which claims human lives, creatures' lives, annihilate properties, streets, make the rich land unusable and harm financial matters and the earth. The glimmer floods happen because of the overwhelming precipitation moist break or release of abruptly overabundance water from the damps. Ordinary floods are normal and for the most part invited in numerous pieces of the world as they give rich soil and water, however flooding at a surprising scale (harming flood) and with unreasonable recurrence make harm life, occupations and the earth. To reduce the damage and fatalities it is required to develop a technique, measure and methodologies to understand the flood risk and vulnerability which can help decision makers.

Over the previous decades, the example of floods over the sum total of what main land has been evolving, ending up increasingly visit, extraordinary and capricious for neighborhood networks, especially as issues of advancement and neediness have driven more individuals to live in territories helpless against flooding. The Fourth Assessment Report (2007) of the Intergovernmental Panel on Climate Change (IPCC) predicts that 'substantial precipitation occasions, which are in all respects prone to increment in recurrence, will increase flood hazard'. These floods will influence life and jobs in human settlements on the whole zones, e.g., waterfront zones, waterway deltas and mountains. Despite the fact that there were nonstop endeavors to moderate flood and its impacts on exploited people. Floods ordinarily become a mind boggling occasion and caused a scope of human vulnerabilities, wrong advancement arranging and atmosphere inconstancy except for glimmer floods, whose scale and nature are regularly less certain. Subsequently it requires increasingly extensive examinations about flood to plan appropriate techniques to improve flood and its effects

1.1.1 **Affect of flood in International region**

Due to the expansion of human settlement and rapid urbanization most of the developing countries without proper planning It cause the greatest damage various kind of natural disaster on a global scale. This natural disasters leading loss of life and injuries, disturbing social, economic, ecological systems, and destroying properties (Bakkensen et al., 2017), and affect the greatest number of people.

In 2017, according to EM-DAT: (Cred Crunch March 2018) indicates that 318 natural disasters occurred, affecting 122 countries. The effect of which bring about 9,503 deaths, 96 million individuals influenced and US$ 314 billion in monetary harms. According to the report 90% of deaths in (2017) were expected to climatological, hydrological or meteorological debacles and 60% of individuals (just about 5,700) influenced by calamities in 2017 were by floods In particular India witnessed the highest burden of natural disaster in 2017 with almost 2,300 deaths and 22,5 million people affected by flood and storm. According to (Cred Crunch March 2018, Issue No.50) show Annual occurrence and economic damages: 1990-2017 disasters (Figure 1.1)

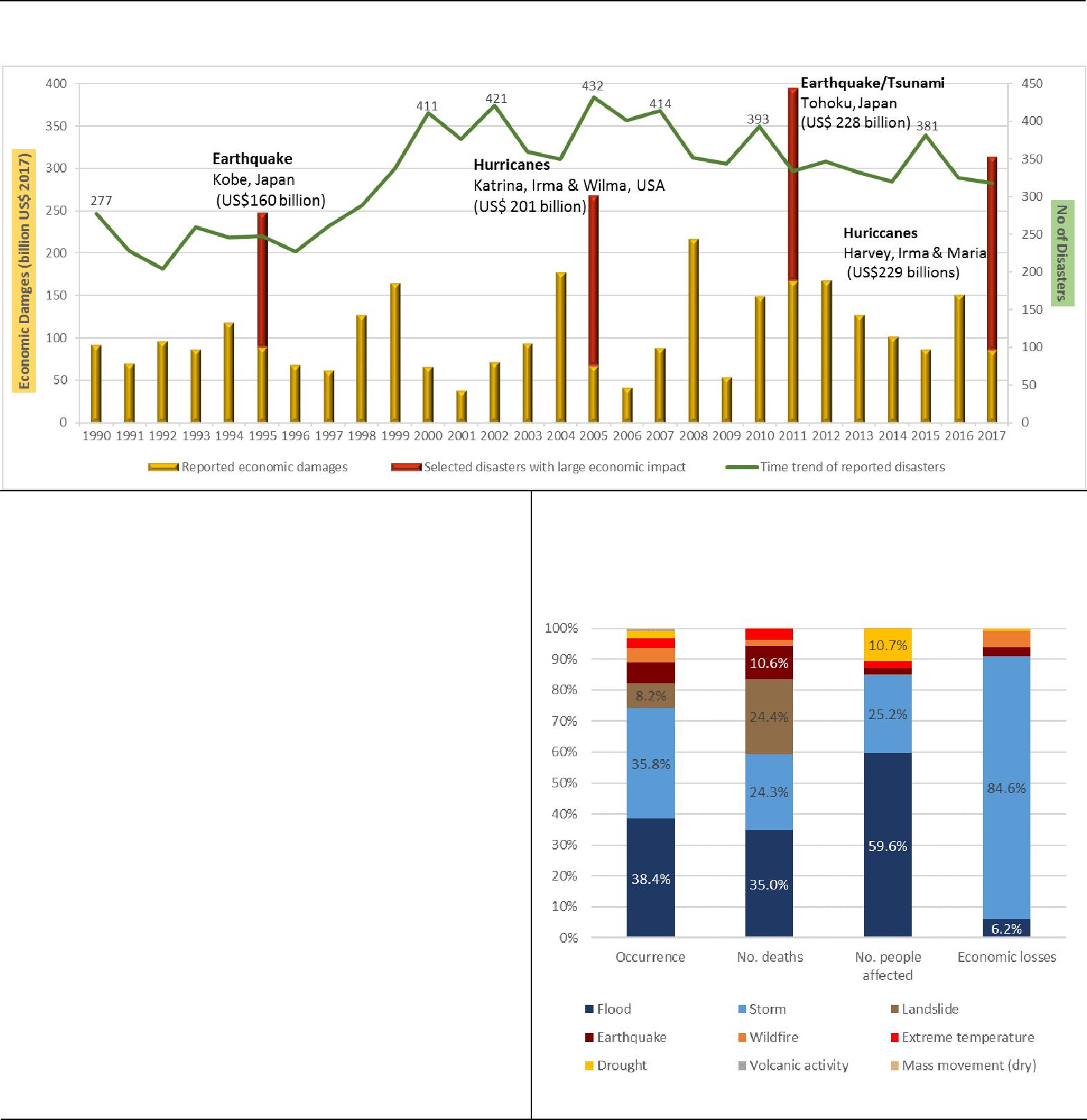


Figure 1.1 Annual occurrence and economic damages: 1990-2017

Source: [EM-DAT: CRED IDD 2018]

In fact, as the 10 most affected countries (Human impact in 2017) are shown in figure 1.2(a) No. of deaths, Figure 1.2(b) No. of people affected (million) and 10 most affected countries ( Economic impact in 2017) in Figure 1.3(c) EM-DAT : [Cred Crunch March 2018]

Human impact in 2017

Economic impact in 2017

In 2002, 700 people deaths and half million people becomes homeless due to the devastating flood in Mozambique. (Weather, 2006) central Europe in 2002 devastating flood required the widespread evacuation of the many town , cities and damages property estimated at 21.5 billion Euros (Weather, 2006) August 2005 flooding in central Europe caused fatalities in Switzerland, Austria, Romania and Bulgaria (weather, 2006). A flood of southern China in June 2010 more than 29 million people were affected and 1.6 hectors of agriculture lands are inundated and approx 5.03 billion euros direct economic loss( IFRC,2010).

* + 1. **National region**

India is the second largest flood affected country in the world. India has been generally powerless against catastrophic events because of its one of a kind geo-climatic conditions.

Recently in Mumbai on July 26 2005, 940 millimeter of rain fall was recorded in single events, results a flood where more than 1000 deaths were reported and 5 million people were affected (Wheater, 2010). In the month of June 2013, Uttarakhand India suffered its worst disaster in the time of history due to the clouds burst a natural disaster a total 169 people died and 4,021 were reported missing about 4,200 villages affected, 11,901 live stock were lost and 2,513 houses completely damaged [Uttarakhand disaster, 2013] Among the recent incidents only in august 2018, the state of Kerala, India experienced large scale of flooding ever since 1924. Between August 7th and 20th, 23 million of people are directly affected and 504 people were died by these flash flood. In this disaster Monetary misfortunes represented 2.85 billion US$, harmed or wrecked 110,000 houses, and profoundly influenced individuals' jobs, with in excess of 60,000 ha of agriculture harmed and many animals killed. At last, these floods harmed in excess of 130 bridges and 83,000 km of streets, causing the confinement of specific networks.

(CRED Crunch53, 2018)

A survey conducted by Central Water Commission, Government of India 2012 indicated that the area liable to be flooded is 426.255 million hectres while the average area affected by floods annually is about 7.225 million hectares (Ref. via letter no. 3/38/2011-FFM/2200- 2291, dated. 2012, Central Water Commission). The Table 1.1 shows that the total damage to property damages crops, houses and public utilities in terms of money comes to as high as Rs 213114.905 ( Ibid) .

**Table 1.1**

**Statement Showing Damage due to Flood during 1953 – 2011in India**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Years 1953-2011 | Area affected in m.ha | Population affected in million | Damage to crops | | Damage to House | | Cattle lost in Nos. | Human lives lost in Nos. | Damage to Public Utilities Rs. Crore | Total damage crops, houses and public utilities in Rs. Crore |
| Area in Ha | Value in Rs. Crore | No. | **Value in Rs. Crore** |
| Total | 426.255 | 1913.386 | 223.573 | 66009.64 | 74042272 | 33373.32 | 5699000 | 97551 | 110203.3 | 213114.9 05 |
| Average | 7.225 | 32.43 | 3.789 | 1118.807 | 1254954 | 565.649 | 96593 | 1653 | 1867.852 | 3612.117 |
| Maximum | 17.5 | 70.45 | 12.299 | 7307.23 | 3507542 | 10809.8 | 618248 | 11316 | 17509.35 | 32554.775 |
| Source: Central Water Commission, GOI, 2012 | | | | | | | | |  |  |

However, the most vulnerable states are Uttar Pradesh, Bihar, Assam, West Bengal, Gujarat, Orissa, Andhra Pradesh, Kerala, Madhya Pradesh, Maharashtra, Punjab and Jammu & Kashmir (Ibid).

According to the Dartmouth Observatory, the north eastern parts of India, the northern banks of the Ganga and its tributaries in Bihar and West Bengal are the most flood prone areas in India (ibid). Scholars have identified the Brahmaputra-Ganges- Meghna basin as one of the worst perennial flood affected areas of the region.

Nature of flood in Brahmaputra – Ganges –Meghna basin:

The annual normal flood between June and October, related with the monsoons rain into the entire Brahmaputra- Ganges-Meghna basins, makes the land fertile by “providing moisture and fresh silt to the soil that are vital to crop production; thousands of species of fish also spawn during this time of year. Peasants of this region, awaits this predictable, normal, annual event that benefits their crop cycle and virtually rejuvenates their lives” (Das, 2013)

* + 1. **Flood affect in Assam and BTAD**

Flood is one of the natural calamities that ravages in Assam state every year. The strong river Brahmaputra affected by the Southwest rainstorm is liable to repetitive floods. Above 80% of community depends on agriculture but since more than 60 years Assam has been facing huge river erosion problems, which is closely related to flood problem. Erosion along with flood has destroyed bunches agriculture product and different fruits and houses of the individuals (Khan, 2012). Khan says that "river disintegration implies ebb and flow of waterway or wave of water of the stream broken the banks of the waterways which collects immense mud and siltation in stream bed and holding limit of water decrease in the waterway and makes flood and disintegration Assam". The recurrence of flood and erosion continued being the expending issue of Assam. Reliably in Assam the floods leave a trail of demolition, washing without end towns, submerging paddy fields, suffocating tamed creatures, other than causing loss of human life and property in billions. The flood hazard made by Brahmaputra river and its tributaries causes ruin in the valley prompting immense misfortune and decimation of life and property of the general population and weakening in the nature of condition (Sabha pandit, 2003). The flood circumstance changes each year since its force shifts relying upon the precipitation got in the catchment regions and aggradations of river and subsequent rupture of embankment in different places. The province of Assam is influenced by the surges of the river Brahmaputra and Barak which have their own characteristics. The catchment of Brahmaputra is characterized by vey steep hill slopes with light texture and unstable soil mass in the recent years. This causes high instantaneous run-off, heavy siltation in the tributaries as well as main stem of river Brahmaputra. It has 41 important tributaries-26 located on the Northern bank and 15 on the Southern bank in addition to the 3 main tributaries-the Dehang, the Dibang and Lohit. The river flows for a length of 640 Kms in Assam. Similarly, the Barak river which causes flood problems in Cachar valley has a catchment area in Meghalaya, Manipur, Mizoram and Tripura. The Barak is a wandering sort of river and changes its course at numerous focuses disintegrating fruitful terrains and causing extreme flood hazards. Brahmaputra valley has consistently been flood inclined. Notwithstanding when the Himalayan watershed was uninhabited and the woodland spread was unblemished, significant floods occurred in the valley. The geographically the Himalayas affected by serious precipitation and seismicity, load the principle river and the tributaries with colossal measure of residue. The northern tributaries with coarser and higher sediment load create more floods and siltation problem than the southern bank of the main river. Floods and shifting of the river courses is thus inevitable. As the volume of water is greatly increased during the flood, so increases its erosive power and the river carries a much higher sediment load. Water and sediment move out of these mountains in explosive waves (Mahanta, 2000). Anthropogenic floods are brought about by disappointment of man-made dams and breaking of artificial embankment. Floods made by breaking of artifical embankment or dykes are a typical highlights in the Brahmaputra bowl. Inception of development of counterfeit dykes occurred in 1954 and from that time Assam has the longest arrangement of dykes built so far in India. A large portion of the dykes have been developed exceptionally near river and with sandy free materials. These dykes are not appropriately kept up. Subsequently, they got broke because of high weight of rising water. Rupturing of dykes caused broad harm in light of the fact that the ebb and flow of the rising water going into the fields happens to be high (Sharma, 2004). The common surges of typically high extents have accepted devastating measurements intensely influencing the farming grounds, yields, individuals and castles or more all the agrarian economy of the state. As regards flood damages in the Brahmaputra valley, the frequency and time of flood occurrence are of great significance. The valley commonly receives severe floods of different orders occurring at least 4-5 times in a year. Normally about 40% area of the valley is affected by flood. The flood of 1988 has been recognized as the year of most severe flood occurring in four waves (Borah, 2015). Assam is perhaps India's most flood-prone state and has experienced at least 14 major floods since 1950 excluding the regular annual flood. Although always prone to floods, the recurrence of heartbreaking floods was expanded in the zone after the 1950 Assam-Tibet seismic tremor, additionally alluded to as the "1950 Great Earthquake". Table 1.2 presents a summary of the flood damages in Assam for the period of 2005-2015. It is seen that in this period total 30224 villages submersed under water, 2017244 hectares cropped area land affected, 118250 houses damaged, 7889256 people affected and 381person died.

Almost all the district of Assam experienced flood in almost every year. BTAD (Bodoland Territorial Area District) also affected by divesting flood in every year. Tables 1.3 show that some district of BTAD happens to be one of the worst hit by the flood problem amongst all the districts of Assam.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Table 1.2 | | | | | | | |
| Statistics on affect of Damages caused by floods in Assam | | | | | | | |
| Item | 2005 | 2006 | 2007 | 2008 | 2010 | 2013 | 2014 | | 2015 | Total |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | 9 |
| Area affected (in Hectares) | 222410 | 57732 | 1504146 | 416000 | N.A | N.A | N.A | | N.A | 2200288 |
| No. of Villages affected | 1563 | 916 | 10295 | 3019 | 3630 | 1592 | 4446 | | 4763 | 30224 |
| Crop area affected (in Hectares) | 98434 | 10406 | 674671 | 314000 | 147038 | 71213.79 | 372178 | | 329303 | 2017244 |
| Value of crop lost ( Rs.in Lakh) | 2347.26 | 111.04 | N.A | 329 | 3678.87 |  |  | |  | 6466.17 |
| Population affected (in ‘000) | 1025 | 555 | 10868 | 2906 | 2546 | 848 | 4203609 | | 3666908 | 7889265 |
| Value of House damaged ( Rs. In Lakhs) | 93440.01 | 163.06 | N.A. | 29335 | 1099.6 | - |  | |  | 124037 |
| No. of cattle lost | 15 | 28 | N.A. | 8002 | 3754 | 181114 | 28 | | 212 | 193153 |
| House damaged (fully) | 9286 | 2270 | 15846 | 30315 | 4864 | 44 | 54088 | | 1537 | 118250 |
| House damaged (partially) | 1503 | 5076 | N.A. | 26235 | 49638 | 547 | 82095 | | 1955 | 167049 |
| No. Human Life Lost. | 29 | 7 | 134 | 40 | 17 | Nill | 90 | | 64 | 381 |
| Source: Office of the chief Engineer, Water resources Deptt and State Disaster Management Authority Guwahati, Assam. | | | | | | | | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 1.3** | | | | | | |
| Statistics on affect of Damages caused by floods in District of Assam | | | | | | |
| **District** | No. of village affected | Cropped area affected in hac | Population affected in No. | No of house Damaged | No. of cattle lost | No. of human lives lost |
| Dhubri | 946 | 17564 | 1065104 |  | 240247 | 15 |
| **Kokrajhar** | 94 | 24445 | 15691 |  | 24707 | 10 |
| Bongaigaon | 240 | 15672 | 269793 |  | 72201 | 9 |
| **Chirang** | 136 | 10164 | 21118 | 33 | 4250 |  |
| Gaolpara | 395 | 3406 | 73341 |  | 15222 | 3 |
| **Baksa** | 1 | 17.5 | 1060 |  |  | 1 |
| Borpeta | 507 | 28108 | 507461 | 62 | 206198 | 3 |
| Nalbari | 105 | 7083 | 156565 |  | 21163 | 3 |
| **Udalguri** |  |  |  |  |  |  |
| Kamrup Metro | 45 |  | 5020 |  | 14225 | 9 |
| Kamrup Rural | 90 | 2983 | 11000 |  | 36270 | 2 |
| Darrang | 113 | 1182 | 113281 |  | 87212 | 4 |
| Sonitpur | 90 |  | 113395 |  | 4756 | 7 |
| Lakhimpur | 292 | 10955.6 | 89992 | 12 | 0 | 12 |
| Dhemaji | 238 | 12995 | 116110 |  | 3871 | 9 |
| Morigaon | 861 | 58447.6 | 694083 |  | 102159 | 29 |
| Golaghat | 201 | 16201 | 219606 |  | 47522 | 8 |
| Jorhat | 85 | 3459.7 | 32406 |  | 53756 | 6 |
| Sibsagar | 95 | 1270.5 | 9507 |  | 5502 | 6 |
| Dibrugarh | 68 | 3174 | 38353 |  | 40408 | 2 |
| Tinsukia | 21 |  | 14471 |  | 16927 |  |
| Nagaon | 231 | 15189.6 | 162807 |  | 49984 | 9 |
| Karbi along | 23 | 227 | 5788 |  |  |  |
| N. C Hills |  |  |  |  |  |  |
| Karimganj | 154 | 8006.5 | 138934 |  |  | 3 |
| Hailakandi | 45 | 169 | 1010 |  |  |  |
| Cachar | 28 | 151 | 46279 |  |  | 1 |
| Biswanath | 153 | 8771.2 | 100344 |  | 16618 | 2 |
| south Salmara | 460 | 6619 | 581790 |  | 228416 | 9 |
| Majuli | 88 | 18326 | 102223 |  | 153011 | 1 |
| Charaideo | 6 | 93 | 1356 |  |  | 1 |
| Dimahasaw |  |  |  |  |  | 3 |
| Hojai |  |  |  |  |  |  |
| Total | 5811 | 274680.1 | 4707888 | 107 | 1444625 | 167 |
| **Source: Flood Report, Water resources Deptt. And State Disaster Management Authority Guwahati, Assam.** | | | | | | |

Almost all area of BTAD (Bodoland Territorial Area District) also affected by divesting flood in every year. The area under BTC (Bodoland Territorial Council) jurisdiction is called Bodoland Territorial Area District (BTAD). The BTAD consist of four contiguous district- Kokrajhar, Chirang, Baksa, Udalguri curved out of seven existing district- kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamrup, Darrang, Sonitpur. BTAD is formed under the sixth scheduled of the constitution of India in 2003. The area has many rivers tributaries of the Brahmaputra. Some of the main rivers are Sankosh, Tipkai, Gaurang, Champabati, Aie, Manas, Beki, Pagladia, Puthimari, Pahumar, Kaldia, Brnadi, Pannoi, Dhansiri, Jiya Dhinsiri, Mora Dhinsiri, Nao, Kulsi, Dipila and Bornoi which are originated from Bhutan foothills.

During summer (May to Early September), heavy rainfall occurs because of south-west monsoon for which the all district experiences flood.

**Table 1.4**

**Statistics on affect of damages caused by flood in BTAD 2015 and 2017**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **District** | | No. of Circle affected | No. of Village affected | Cropped land affected (ha.) | No. population affected | Human life lost |
| **2015** | kokrajhar | 1 | 8 | 705 | 1285 | 8 |
| Chirang | - | - | - | - |  |
| Baksa | 5 | 62 | - | 50,122 |  |
| Udalguri | 3 | 16 | 294 | 740 |  |
| **2017** | kokrajhar | 5 | 82 | 24445 | 13191 | 10 |
| Chirang | 4 | 135 | 10164 | 20908 |  |
| Baksa | 1 | 1 | 17.5 | 1060 | 1 |
| Udalguri | - | - | - | - |  |
| Source: Daily\_flood\_report,2015,2017, ASDM | | | | | | |

As shown in the table 1.4, in 2015 only 86 villages are submersed 999.5 hectares of crops land more than 55,000 people were affected. In Baksa district embankment were washed away at Deosunga in Deosunga river, at Wiz kashula in Puthinari river and at Harjhara in Puthimari river. The roads washed away are Gorbhitor Tamulpur road, Gorbitor Bherbhari road, approach road to Daodhara to Doomni and Kesan nagar doomni nagar approach road all washed away. Wooden bridges at Shimla bazaar, Bamboo bridge at Madaltona Jhakuchi road are all washed away. (daily\_flood\_report, ADMA 2015) The flood of 2017 BTAD has been hit by floods with 218 villages in flood-prone BTAD inundated. The flood water has inundated 82 villages of kokrajhar district under Kokrajhar, Dotma, Bogribari, Gossaigaon and Bhawraguri, circles in west Kokrajhar affecting more than 13191 people damaging 24,445 (hectares) of cropped land area and lost of 10 human live. In Chirang district flood water inundated 134 villages under sidli, Bengtol and Bijni circle more than 25,000 people

Flood can deliver across the board impacts in both rural and urban zones however it is the towns, property harm brought about by flood can be crushing to ranchers. When flood occurs during the growing season, farmers can suffer widespread crop loss. In some cases, there may be an opportunity for a second planting of a less profitable crop. Livestock farmers may lose livestock if they are unable to find safety from rising floodwaters. This threat is primarily associated with flash flooding where the monsoons flood. Any type of agricultural, commercial, or residential development located in a floodplain is vulnerable to flooding. Flood can create several threats to residential and commercial properties. In villages thatched houses are damage to the extent of beyond repair. Indeed, even some pucca structures experience huge harm, here and there destroyed, because of flooding. Family unit goods and business inventories can be lost if there isn't enough time to evacuate things to safe areas. Indeed, even wild creatures, constrained out of their homes and carried into contact with people by floodwaters, can be a risk. Extreme flood can cause wide-going harm to network utilities and disturbances to the conveyance of administrations. Loss of intensity and interchanges can be normal. Drinking water and wastewater treatment office might be briefly out of activity. Thus, all these enhance the sufferings of the people. Social system gets affected, as families in large number come to reside in temporary camps leaving their all belongings behind. Their inundated houses get damaged. Camp life provides a completely different system of environment where there is neither any social control mechanism nor any social institution to rely on Social financial and political foundations stay dead and even after retreat of floods it requires investment to restore and resuscitating these organizations

These two Kokrajhar and Chirang districts are the worst affected in terms of frequency and duration of flood (Table 1.4). The Saddest suffering of the people here during floods continues and gets complicated even after the floods recede in the form of sand deposits over the highly productive agriculture lands.

### LITERATURE SURVEY

The challenge to argue pragmatic issues on flood hazards and flood management has motivated and inspired researchers to carry on the theoretical and applied aspects of flood disaster. Their research designs and findings have stimulated academic and professional inquiries for further research. In this thesis the author has gone through some of the works from published books, Journals, Newspapers and records to get acquainted with the basic principles of flood hazards and its management. Research on water resources have been encouraged all over the world. Flood is a common disaster in every country of our World.

There are two principal types of measures being considered for the management of river floods: (a) non-structural measures and (b) structural measures; (Simonovic, 1999).

* + 1. **Conceptualization of flood risk and vulnerability**

Over the last two decades the concept of vulnerability has changed frequently since it’s been used in different disaster studies and subsequently there have been a few endeavors to characterize the term of vulnerability. There is a set of concepts including vulnerability in literature, competing ability, adaptability, flexibility, risk and risk associated with flood risk. The relationship between these conditions is often unclear, and various references in this context and various background researchers may have different meanings (Bharavani et al., 2008).

Therefore, it is necessary to clearly understand the specifics of each idea. Gabor and (Griffith,1980) defined vulnerability as the risk context and the frequency of a dangerous accident. (Chambers, 1989) explained the vulnerability "as a potential leak" on two sides: external shocks and internal resilience. (Watts and Bohle, 1993) analyzed social vulnerability, taking into consideration the threats and reactions of societies to face immunity. (Cutter, 1993) and (Cutter, 1996) defined susceptibility as a threat, including natural hazards and social actions and reactions, according to (Coburn et al., 1994), the vulnerability is defined as "the degree of loss of a given element of risk (or elements of the whole) resulting from a given danger at a given level of gravity". (Klein and Nicholls, 1999) explained this vulnerability as a function of the natural environment, using three elements: resistance, resistance and vulnerability, and (Lewis, 1999) described that "vulnerability is the main cause of disasters", and (Merz et al., 2007) stated that this is a function of the definition of susceptibility to risk, exposure and vulnerability elements

Some frameworks believe that the vulnerability is composed of exposure (how people are exposed to disasters) and susceptibility (what is the probability that they will be damaged) (UNDP, 2014). However, in this study, vulnerability is considered an intrinsic characteristic of a good and therefore independent of the entity of a specific risk but depends on the context in which it occurs (Rashed and Weeks, 2003). Therefore, the vulnerability does not change if the risk is more intense or less: it is the exposure that could change and influence the degree of risk (Fuchs, 2009). Vulnerability assessment regardless of risk has the advantage that it can be applied to any risk of flooding, be it small or large rivers, or extended to coastal floods or sudden floods (Fekete, 2012).

**1.2.2 Flood risk expressions**

The strategy for dealing with a flood risk occasion is named as the flood risk management (Plate, 2002). The term of risk is characterized as "the likelihood that a hazard will transform into a fiasco" (Balica et al. 2009). Vulnerability and hazard don't characterize risk independently, yet they are joined to appraise the risk as displayed in Equation (2.1).

Risk=Hazard×Vulnerability (2.1)

Where, risk is the result, and the hazard and vulnerability are reason and base individually.

Likewise, risk can be clarified as "the likelihood of event of an occasion duplicated by the occasion results" (Bouma et al., 2005). Risk=Probability X Effect

(Barredo et al., 2007) utilized underneath capacity to assess the flood risk:

Flood risk=f (Hazard,Exposure,Vulnerability)

Within this outline, a hazard is a risky marvel of a given size and recurrence that happens in a particular territory (Thouret et al., 2013). A flood itself is a hazard which is normally spoken to as maps that show flood qualities, for example, immersion profundity, stream speed and immersion length (Ward et al., 2011). The estimation of the flood hazard is generally performed utilizing hydrologic and pressure driven hydrodynamic models that permit evaluating the flood top and the proliferation in reality of the flood wave (Sampson et al., 2015). The hazard occasion isn't the sole driver of risk. Without a doubt, the antagonistic effects of catastrophes are essentially controlled by the vulnerability and exposure of social orders and social-natural frameworks. (Cardona et al., 2012). Consequently, individuals and different resources must be presented to hazards for these occasions to progress toward becoming debacles, generally, the risk will be zero (Takara, 2013).

The term exposure alludes to the components situated in a zone in which a characteristic marvel may happen (UNISDR, 2009). These includes, for instance, individuals, their jobs, properties, monetary exercises, physical foundations, and natural administrations and assets. Besides, exposure can likewise be separated into a fleeting and spatial segment, since networks may be presented spatially to a specific degree and additionally over a particular timespan, because of their working environment or spot of living arrangement (Welle and Birkmann, 2015). The measurements used to dissect the exposure more often than not include the quantity of individuals or resources situated in possibly hazard-inclined territories.

Like the hazard, exposure is a fundamental, however not an adequate determinant of risk. Along these lines, it is conceivable to be presented to a hazard however not be helpless. For instance, an individual can live in a floodplain however have adequate intends to adjust the structure to relieve potential misfortunes (Cardona et al., 2012). Accordingly, the administration of flood risk requires a superior comprehension of vulnerability

A main part of vulnerability is the coping limit, which alludes to the positive highlights of a framework that may decrease the risk presented by a specific hazard. Inside the setting of this study, coping limit is characterized as the capacity of individuals, associations, and frameworks, utilizing accessible aptitudes and assets, to confront and oversee unfriendly conditions, crises or debacles (UNISDR, 2009). These limits can be related with existing assets that help to confront and oversee crises, for example, pertinent foundations, early cautioning frameworks, medicinal consideration, and emergency clinic limits. On the other hand, the absence of these limits can likewise be considered, for instance, with respect to the arrangement of an effective common assurance framework or the choice to buy a insurance against normal hazards (Welle and Birkmann, 2015).

The positive side of vulnerability can likewise consolidate the adaptive capacity. As opposed to the coping capacity which is principally momentary arranged, adjustment is characterized as a long haul organized procedure that means to decrease the effects of a hazard (Cardona et al., 2012; O'Brien and Vogel, 2003). It incorporates measures and methodologies that empower networks to change and to change so as to manage anticipated negative outcomes of common hazards. Thus, these limits center around assets that permit changing structures inside a general public (Welle and Birkmann, 2015).

The term resilience develops vulnerability and might be seen as the characteristics the capacity of a framework, network or society presented to hazards to oppose, assimilate, oblige, adjust to, change and recoup from the effects of a hazard in a convenient and proficient way, including through the conservation and rebuilding of its fundamental essential structures and capacities through risk the executives (UNISDR, 2009). The present writing uncovers various understandings of the term resilience, particularly concerning the subject of whether it ought to be joined into the idea of vulnerability (Birkmann, 2006). Surely, as indicated by certain analysts, resilience is a basic piece of vulnerability (Figure 1.3a), while others frequently install adaptive capacity inside resilience (Figure 1.3b). A third viewpoint considers resilience to be vulnerability as independent yet regularly connected ideas (Figure 1.3c) (Cutter et al., 2008). Despite the system embraced Gall (2013) points out that while vulnerability can be viewed as a genuinely static idea, resilience is dynamic in nature. It contains questionable input circles and collaboration effects, changing with interior conditions, outside powers, and with the network's capacity to react to floods. Thus, considering the apparently unconquerable applied just as methodological difficulties in resilience appraisal, this examination does not endeavor to quantify it.

**Figure 1.3**. Conceptual linkages between vulnerability, resilience, and adaptive capacity according to different perspectives (Redrawn from Cutter et al., 2008)

(a)

(b)

(c)

Vulnerability

Vulnerability

Resilience

Resilience

Resilience

Adaptive

Capacity

**1.2.3 Methods to assess flood vulnerability**

The evaluation of vulnerability gives significant data to all periods of the risk the board cycle. Prior to the event of a flood, data in regards to the vulnerability of the components at risk may control the foundation of crisis plans and asset assignment. During the event of floods, salvage teams may utilize vulnerability maps to figure out where to react first to spare individuals that need help. After the catastrophe, the consequences of vulnerability examination can be contrasted with the genuine harm with improve the precision of risk maps (Edwards et al., 2007).

Despite the fact that vulnerability is a key issue in understanding debacle risk, its evaluation is as an unpredictable errand since it is beyond the realm of imagination to straightforwardly gauge it (Jongman et al., 2015; Koks et al., 2015). As an outcome, there stays little agreement on the most ideal approach to survey vulnerability. There are even the individuals who contend that vulnerability as an idea can’t be sufficiently measured (Hinkel et al., 2011) and henceforth are "immeasurable" (Birkmann and Wisner, 2006).

As of late, the quantity of publication related to the estimation of risk and vulnerability has expanded. (Birkmann, 2006) gives a broad arrangement of approaches for various scales and levels. When all is said in done, the methodologies used to assess vulnerability can be ordered into: (1) vulnerability curves (Tsubaki et al., 2016); (2) damage matrices ( Papathoma-Köhle et al., 2017); and (3) vulnerability indicators (Cutter et al., 2003; Roy and Blaschke, 2015).

Vulnerability curves : Vulnerability curves, likewise alluded to as damage curves, state-damage curves or capacities, relate the normal damage of an individual component at risk with the hazard intensity. More often than not, the flood profundity is utilized as a proportion of the intensity (for example moderately high damage rates for a given immersion profundity). By and by, other hazard parameters, for example, speed and length are sometimes utilized (Jongman et al., 2012; Merz et al., 2010). The curves can be inferred utilizing observational, master judgment, expository, and crossover draws near (Godfrey et al., 2015a).

Vulnerability matrices, which depend on the presumption that a given component at risk will show a similar degree of damage when submitted to a hazard with comparative intensity (Godfrey et al., 2015a). The matrices are created dependent on experimental information, factual examination or master judgment. Structures that have not been damaged by the occasion are given a lower vulnerability score and the ones that are completely damaged get a higher worth. This methodology makes the connection among hazard and effects clear and straightforward by non-specialists. Notwithstanding, the strategy is emotional as the subjective depiction of the damage levels may vary among specialists. Consequently, transferability and correlation potential outcomes are constrained (Papathoma-Köhle et al., 2017).

In the IPCC (2007), risk is a result of the probability of a hazardous condition and the outcomes of that

The most recent IPCC report (IPCC 2014) utilized the term of risk to allude "the potential, when the result is questionable, for antagonistic outcomes on lives, occupations, wellbeing, biological systems and species, financial, social and social resources, administrations (counting natural administrations) and foundation".

* + 1. **Vulnerability indicators**:

Since an immediate measurement of vulnerability is preposterous, a marker or a lot of indicators ought to be utilized to quantify the state of a framework as a natural characteristic (Balica et al. 2012; Cutter et al., 2003). Gomez (2001) noticed that indicators should concentrate on quantifiable and justifiable little parts of a framework and give individuals a feeling of a greater picture. Truth be told, indicators are input information can be utilized in pointer based strategy to choose flood vulnerability of a region. Considering explicit indicators can evaluate the frameworks vulnerability, which can prompt recognizing activities expected to diminish the vulnerability (Balica et al. 2012).

In the indicator- based vulnerability assessment, the initial step is choosing legitimate least number of indicators (Sullivan 2002). Routine practice for indicator choice is following an applied system to set up a rundown of them thinking about appropriateness, helpfulness and memory process (Balica et al. 2012). Chosen indicators should cover real conditions and mirror the basics of flood catastrophe in any framework (Li et al. 2013)

Strategies which are utilized to choose indicators of FVIs are comprehensively gathered into 2: quantitative techniques (which depend on master's conclusions) and subjective strategies (measurable methodologies). Among various subjective strategies Principal Component Analysis (PCA) has been generally utilized in writing to choose indicators (Ka źmierczak and Cavan 2011; Zhang and You 2013). The primary quantitative strategies to choose indicators are Analytic Hierarchical Process (AHP), Delphi procedure and Participatory Rapid Analysis (PRA). Furthermore, Balica et al. (2012) utilized a deductive way to deal with recognize the best indicators regarding the vulnerability applied casing work. As an elective methodology, Barroca et al. (2006) led broad writing audit on neighborhood undertakings to distinguish and finish best indicators.

* 1. **FUZZY LOGIC APPROACH IN HYDROLOGY**

Introduction of Fuzzy set theory (Zadeh, 1965) which deal with uncertainty and sources of vagueness has been utilized for incorporating imprecise data into decision framework. It provides a simple way to reason with vague, ambiguous and imprecise input or knowledge, which seems adapted to the context of modeling, risk and crisis management in a first view. Fuzzy rule-based modelling can be considered as an extension of FL. This type of modelling has a high potential in some cases when a causal relationship is well established but is difficult to calculate under real life conditions and scarce data situations (Sen, 2001).

(Hundecha et al., 2001) Contributed a fuzzy guideline based routine model for every one of the modules chose, and application and approval of the model was done on a precipitation overflow examination of the Neckar River catchment, in southwest Germany.

(Aketer *et al*., 2004) introduced a methodology for a flood assessment decision making problem by taking objective to capture and aggregate the perspectives on different partners utilizing fuzzy set hypothesis and fuzzy rationale. Three likely reaction types: scale (fresh), semantic (fuzzy) and restrictive (fuzzy) are dissected to locate the totaled info utilizing Fuzzy Expected Value and applied in the Red River Basin using a generic case study.

(Chen et al., 2004) develops a multi criterion, fuzzy recognition model for flood control tasks. First starting criteria loads are acquired and afterward the elective set is assessed, as per the attributes of constant flood tasks, administrators may additionally change (Jiang et al., 2009) conributed (FCA) fuzzy far reaching appraisal, basic fuzzy order (SFC), and the fuzzy likeness technique (FSM) to assess flood debacle hazard in Kelantan, Malaysia. The result validates and compares three estimation methods: FCA, SFC, and FSM, to find an optimal evaluation according to the amount of validation data in the superior and uppermost risk zones.

(C Lai et al., 2015) contributed a Fuzzy Comprehensive evaluation (FCE) evaluation model to learn flood risk. It was a mixture of weight coordinating abstract weight and target weight which was received dependent on games hypothesis and was utilized to asses flood hazard in the Dongjing River Basin

(Kar et al. ( 2017) presented A soft computing-based flood forecasting model with fuzzy deduction framework is created to study non basic flood control at Mundali station in Mahanadi River, India and the outcomes contrasted and watched values.

The multi criteria decision making (MCDM) procedure is one of the main parts of modern decision Science that contains multi decision criteria and multiple decision alternatives. The goals of the MCDM are to locate the most appropriate options from the diverse built up criteria relying upon the issues. (Opricovic 2007; Ju et al., 2013)

(Fanghua et al, 2009) examined how to utilized a fuzzy multi-criteria collective choice making (FMCGDM) model Based on modified Borda scoring strategy in watershed natural hazard the executives , a two-organize, 12-advance MCDM procedure is proposed to secure the ideal option chose by different chiefs (DMs) from a given options set. Initially, all DMs settle on their own autonomous decision individually, at that point, all the free ends are coordinated by utilizing their subjective/objective weights. An adjusted Borda strategy is pursued to rate and rank the weighted other options; where the one with the most elevated score will be chosen as the last ideal choice. This model is exhibited in Three Gorges Reservoir region situated in the upper ranges of Yangtze River in China.

(Chitsaz et al., 2015) applied useful outlined to prioritize the flood risk management alternatives for Gorganrood River in Iran. A Comparative study also conducted.

The VIKOR method which was devolved by (Opricovic, 1998, 2004) was to take care of multi criteria basic leadership issue with clashing and non-commensurable criteria. This technique depends on an accumulating capacity speaking to "closeness to the thought" which began in trading off programming strategy.

(Opricovic and Tzeng, 2007) built up a way to deal with survey flood defenselessness utilizing the fuzzy-based VIKOR strategy for GDM. The VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian) method which is another MCDM method that applied for aggregating functions; it focus on compromising solutions for a prioritization problem with conflicting criteria, which can help decision makers obtain final solutions.

( Chang et al., 2009) applied Multi criteria VIKOR strategy to build up the best possible arrangement as indicated by the chose criteria, together with geological and meteorological elements. The objective of this study was to affiliation the need positioning of land-use confinements in the Tseng-Wen store wastershed in southern Taiwan. It was done that subdivisions close to the outlet or repository territory ought to have the need of land-use limitations.

(Lee et al., 2013) used fuzzy TOPSIS and the normal loads of leaders to perceive the flood weakness for the decrease of the fresh information vulnerability. Be that as it may, this examination demonstrated another structure to improve the constraint of the past investigation which has not considered the weight contrasts among all partners by presenting the fuzzy VIKOR technique for GDM.

(Kim et al., 2015) contributed the natural attainability scores of ten elective dam building destinations dependent on various criteria VIKOR strategy, including scene and topography, biological worth, water esteem, and ecological poisonous quality, and produces sets of arbitrary numbers to fill the holes coming about because of the incomplete information.

(Malekian et al., 2015) studied Shannon’s Entropy technique and applied the VIKOR strategy to assess the trade off arrangement from a lot of alternatives dependent on subjective and objective weights of the criteria. The arranged system included two unique sorts of affectability examination for exploring the effects of criteria weights' alterations on the last ranking. The proposed integrated MCDM procedure made a valid contribution to the problem.

( Brito et al. 2016) reviewed multi-criteria decision-making (MCDM) applications to flood risk assessment, looking for highlighting trends and identifying research gaps. A total of 128 peer-reviewed papers which are published between 1995 and 2015 were systematically analyzed and he establishes that it grows about 82% of all papers published since 2009. AHP was one of the most outstanding strategies, trailed by Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), and Simple Additive Weighting (SAW). Disregarding the way that there was more noteworthy enthusiasm for MCDM vulnerability analysis stays an issue and was only occasionally applied in flood-related investigations and the author belief that their paper can give profitable data for future research and that it can fill in as a prepared reference for scientists and professionals working with flood hazard management and MCDM.

(Saaty, 1980) developed a model using analytical hierarchy process (AHP) to support in multi-criteria decision making problems. The complexity associated with the categorical and simple linear weighted average ranking methods was conquered.

(Lee et al, 2007) provides an orderly seven stage procedure and utilization of integrated watershed arranging and the board that permits economical improvement in a Korean watershed. This procedure contains different techniques and hydrologic danger positioning procedure and assessment list to evaluate adequacy of option are proposed. This examination fills in as a manual for develop reliable choice emotionally supportive network for integrated watershed the executives

(Sinha et al. 2008) presented flood hazard investigation in the Kosi River Basin, North Bihar utilizing Multi-Parametric methodology utilizing Analytical Hierarchy Process (AHP) and coordinates geomorphological, land spread, topographic and social (populace thickness) parameters to propose a Flood Risk Index (FRI). The flood hazard map is approved with long haul immersion maps and offers a financially savvy answer for arranging moderation quantifies in flood-inclined territories.

(Choudhury ,2010) presented a weighted pre-emptive goal programming model plan for facilitated supply activity, with simple incorporation of uncontrolled water streams. The model is joined with a different water inflows estimating model, and can be utilized for ongoing supply activity. . The model is connected to the flood control activity of stores in the Narmada River Basin (India), with three controlled and three uncontrolled water streams influencing the downstream stream at Hoshangabad. Model applications to the 1999 flood occasion in the Narmada River Basin.

(Das et al., 2011) contributed a multi-arrange various leveled model is created to gauge the aggregative hazard related with the disappointment of crisis reaction framework if there should arise an occurrence of flood. disappointment occasion are characterized utilizing fuzzy numbers to catch ambiguity in the idea of applicable hazard factors. An analytic hierarchy process (AHP) is utilized for evaluating the need framework (weight) for gathering hazard qualities. Utility of a proposed model is shown through a rearranged hazard hierarchy speaking to crisis reaction framework disappointment of a FIM.

(Wang et al., 2011) created semi-quantitative model and fuzzy analytic hierarchy process (FAHP) weighting approach, to evaluated flood chance in the Dongting Lake locale, Hunan Province, Central China. The model was planned utilizing spatial multi-criteria investigation (SMCA) procedures in a Geographic Information System (GIS). A GIS database of markers for the assessment of peril and powerlessness was made, was investigated, institutionalized, and weighted; after which, the loads of the pointers were joined to acquire the last flood chance record map.

(Kandilioti et al., 2012) exhibited A GIS-based multi criteria flood chance appraisal approach was in this way created and applied for the mapping of flood hazard in urban zones. This approach measures the spatial circulation of flood risk and can manage vulnerabilities in criteria esteems and to look at their effect on the general flood risk assessment. The approach is connected to the Greater Athens territory and approved for its focal and most urban part.

(Li et al., 2012) presented flood risk investigation and assessment technique dependent on variable fuzzy set and data dissemination to improve likelihood estimation and set up a fuzzy model to assess flood hazard with deficient informational collections. This paper present a composite strategy dependent on variable fuzzy set - AHP and data dissemination technique for catastrophe hazard evaluation.

(Yang et al., 2013) established a hybrid evaluation model dependent on fuzzy analytic hierarchy process (AHP) and triangular fuzzy number. It contains flood risk evaluation and expectation to acquire risk components positioning and far reaching flood risk forecast, and after that broke down flood risk response measures. A contextual analysis is proposed involving a flood risk evaluation and forecast in the Lower Yangtze River area

(Chang, 2013) contributed a set of criteria from three kinds of factors (hydrologic, geographic, and societal) for evaluating river basin environmental vulnerability. For AHP analysis, seven set of criteria were selected, and the weights were determined. Two different (MCA) multiple criteria analysis techniques, the weighted strategy and the trade off technique, were utilized to consolidate the criteria and surveyed the natural defenselessness of five primary waterway basin in Taiwan. The outcomes shows that the Cho-Shui River Basin has the most noteworthy natural.

(Siddayao et al., 2014) applied Analytical Hierarchy Process (AHP) strategy was joined with a Geographical Information System (GIS) for flood hazard examination and assessment in the town of Enrile, a flood-inclined zone situated in northern Philippines. The AHP results demonstrated the general loads of three distinguished flood hazard factors, and these outcomes were approved to be predictable, utilizing a standard consistency list.

(Wu et al., 2015) set up a flood debacle chance appraisal model dependent on GIS and catastrophic event hazard evaluation hypothesis. Analytic hierarchy process (AHP) strategy in multi files correlation is utilized to limit the event of the irregularity issues.

(Kerkez et al., 2017) introduced the fuzzy analytic hierarchy process (FAHP) model for flood chance evaluations. Two flood danger files were characterized and FAHP is applied to informational collections to represent a model. Procedure was applied in the Huaihe River bowl China. The outcomes show that the multi-year normal hazard zone map from 1960 to 2010 is predictable with the recorded flood debacle appropriation, which confirms the pertinence of this strategy in flood disaster risk assessment.

(Bordaloi,. 1995) Presented Ph. D thesis impact of the Brahmaputra flood and erosion hazard on floodplain occupancies in Palashbari-Nagarbera tract of Kamrup District

(Gogoi ,1997) carried out a research work on Impact of Flood on Human Occupance in Sadiya Region, Assam

(Talukdar., 2005) presented a research thesis on flood hazard in Barpeta District, Assam: environment perspectives.

(Bahttacharjree, 2008) studied impact of flood and bank erosion problems in Darrang District, Assam : A Fluvio-Geomorphological Study.

(Das et al., 2009) studied the adjusting to floods on the Brahmaputra plains, Assam, India.

(Khan., 2012) studied river erosion and its Sicio-economic impact in Barpeta District with sSpecial reference to Mandia Dev. Block of Assam.

(Doley., et al. 2015) presented Causes and Problems of Population Displacement of the Mishings of Dhemaji due to Flood Vulnerability.

1. **SIGNIFICANCE OF THE STUDY**

Bodoland Territorial Area District (BTAD) which consist of four contiguous districts namely kokrajhar, Chirang, Baksa and Udalguri. lies between 26 7’12’’ N to 26 7’50’’ N latitude and 89 47’40’’ E to 92 18’30’’ E longitude. BTAD is situated on the north bank of Brahmaputra waterway in Assam in the North-East India by the lower regions of Bhutan and Arunachal Pradesh. There are a good number of rivers and its tribunals flows from Bhutan through and reached into the Brahmaputra. The inhabited of this region suffers from flood ( june to August) almost every year. So far no liturature of flood study is found in this region.

Keeping this view a study has been done in BTAD area with the following objectives.

1. **OBJECTIVE OF THE STUDY**

The Objectives of study in BTAD is about the flood risk assessment based on fuzzy technique.

* To study about different factors such as Environmental, Social and Economics of flood vulnerability in BTAD area. For this purpose Fuzzy logic based VIKOR method shall be used to find out the hierarchy of the sub-criteria of the above factors respectively.
* To apply the developed fuzzy based Flood Vulnerability factor in the areas under the jurisdiction of BTAD area in Assam. Such an application will identify the areas that are highly vulnerable to floods.
* To study and developed a mathematical model based on fuzzy logic in order to control (reduce) the flood damage in BTAD area.

1.6 **METHODOLOGY:**

General steps of the research methodology are consists of six steps as shown below:

1. Data collection and Selection of alternatives
2. Identification of criteria
3. Formation of expert committee and opinions collection through the linguistic variable for the selected criteria and alternatives.
4. Aggregating the experts opinion using operators such as OWA and Geometric mean method.
5. Finding the criterion weights using Fuzzy AHP and F- VIKOR.
6. Ranking the alternatives.

**1.7 ORGANIZATION OF THE THESIS:**

This thesis comprises six chapters each consisting of several subsections. The briefly discussions of our research topics are as follows:

1. *Chapter 1* includes the motivation and objectives of the research work float by the literature survey and significance of the work, objectives of research work towards the end of the chapter we underline the methodology of the research work.
2. *Chapter 2* includes the basic definitions and results of the form of preliminaries that will required in the subsequences part of the thesis.
3. *Chapter3* provides brief description of our study area we then highlights the data for the fulfillment of our research work
4. *Chapter4* presents the application of Fuzzy VIKOR method to investigate the flood vulnerability region in BTAD. Linguistic variables and expert’s opinion are used to assess the weights of the selected criteria and the rating of the alternatives for flood vulnerability assessment. This achieves the 1st and 2nd objectives of the research.

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1. *Chapter5* presents a FAHP and F VIKOR model for flood control project selection. This model contributes to a partial fulfillment of 3rd objectives. FAHP method is used to find the weights of the selected criteria and then weighted value is used in FVIKOR method to find the best flood control project selection

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1. *Chapter* 6 represents comparison of Multi-Criteria Decision-Making tools for flood control selection such as Fuzzy PROMETHEE, F-TOPSIS, F-VIKOR
2. A details reference of the relevant literature is given in the last part of this thesis

**Chapter-2**

**PRELIMINARIES**

**2.1 BASIC OF FUZZY SET**

**2.2 FUZZY NUMBERS**

**2.3 LINGUISTIC VARIABLES**

**2.4 OVERVIEW OF DECISION MAKING AND ITS SUPPORT**

**2.5 METHODS**

**2.1 BASIC OF FUZZY SET**

In the real world, people often use concepts which are quite vague. For example, we say that a woman is young or very young, an object is costly or cheap, a mango is yellow and rip, a number is big or small, a bike is slow or fast and so on. Let us take *young* as an illustration. Consider *A* is a 25-year-old woman. Maybe we think *A* is certainly young. Now comes a woman *B* only one day younger than *A*. Of course, *A* is still young. Then how about a woman only one day younger than A. Continuing in this way, we shall find it difficult to determine an exact age beyond which a woman will be young. As a matter of fact, there is no sharp line between young and younger. The transition from one concept to the other is gradual. This gradualness results in the vagueness of the concept *young*, which in return makes the boundary of the set of all young women unclear.

Zadeh in (1965 and 1975) introduced Fuzzy set s which is a generalization of conventional set theory. A fuzzy set assigns to each possible individual in the universe of discourse, a value representing its grade of membership in the set. It is concerned with the degree to which events occur rather than the likelihood of their occurrence. Fuzzy logic is most successful in situations with very complex models, where understanding is strictly limited and where human reasoning, human perception, human decision making are inextricably involved. Fuzzy sets assume a significant job in human thinking, especially in the areas examples of pattern recognition, correspondence of data, decision making and abstraction. Applications of fuzzy sets in various fields are discussed in George J. Klir and Bo Yuan

In general set theory an element is either a member of a set or not. We can express this reality with the characteristic function for the elements of a given universe to have a place with specific subset of this universe. We call such a set a *crisp set*.

**Characteristic function:**

The classical set A in the Universal Set X, A⊆X is normally characterized by the function which takes the value 1 and 0, indicating whether or not x ∈X is a member of A?

Here ∈ {0, 1} . The function takes only the values 1 or 0. Now, assumed that the function may take values in the interval [0, 1]. In this way the concept of membership is not crisp any more, but becomes fuzzy in the sense of representing partial belonging or degree of membership.

A fuzzy set is defined and denoted by 



Where is called the membership function;  defines the grade or

degree to which any elements in  belongs to the fuzzy set 

When X finite set or is countable, a fuzzy set  on X is expressed as



When X is a finite set whose elements are x1, x2, ………., xn, a fuzzy set  on x is expressed as



When X is uncountable set and an infinite, a fuzzy set  on X is expressed as



This means that expression is the grade of x is  and the operations ‘/’ is not a algebraic ‘quotient but a delimiter, ' ' is not algebraic ‘add’ but unions and

‘’ do not refer to integral but a continuous function.

**2.1.1 Definitions:**

**Support**

The support of a fuzzy set A n is defined as the fresh set that contains every one of the components with nonzero enrollment reviews in An of X within a widespread set X.

Support of A is denoted as Supp (A) = 

**Core**

The **core** of a fuzzy set A is the set of all points with unit membership degree in A and is represented as core (A) = 

**Normal**

A fuzzy set A of X is called **normal** if there exists at least one element x in X such that A fuzzy set A is normal if its core is nonempty. A fuzzy set that is not normal is called subnormal.

**Height**

The height, of a fuzzy set A is defined as the largest membership grade in A which is obtained by any element in that set. Height (h) is represented as

 in X

**Alpha Cut**

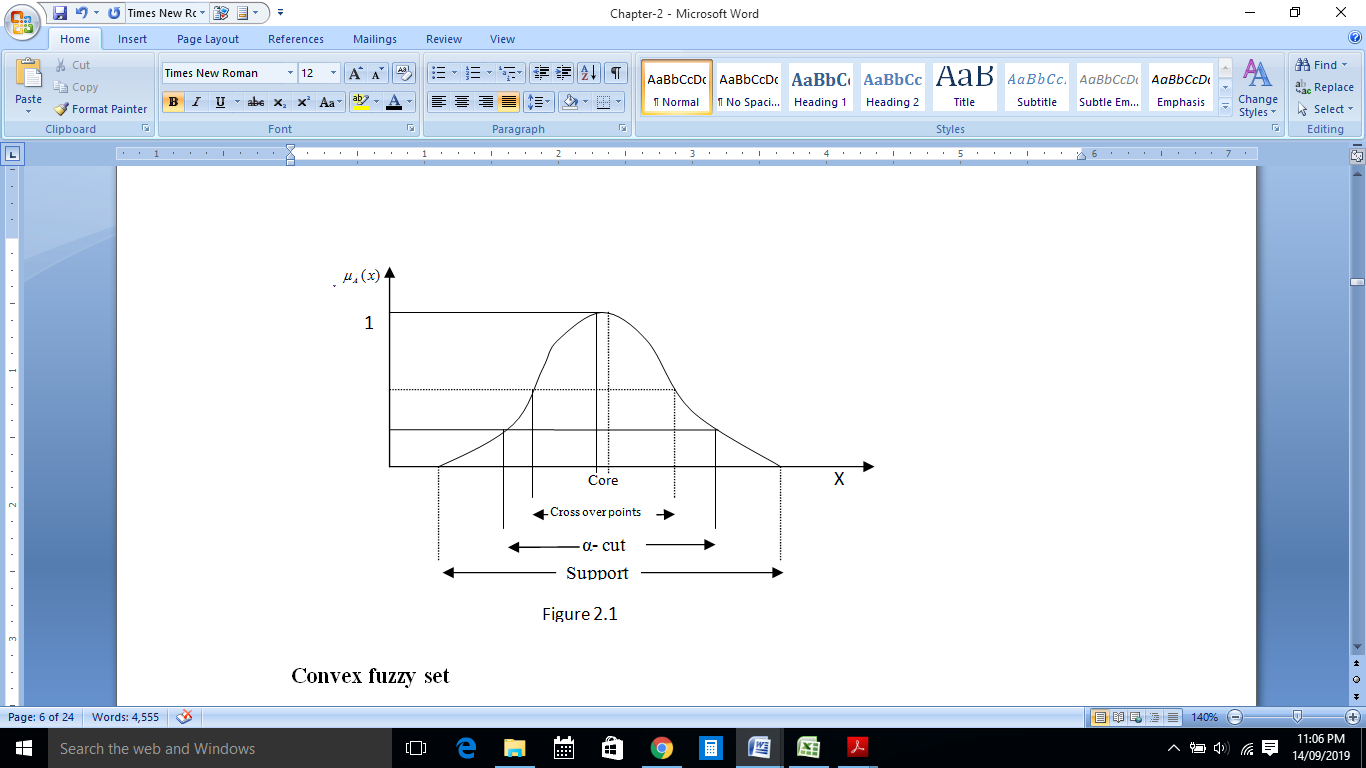
Alpha cut is the most important concepts of fuzzy sets.

For a given fuzzy set A and set of all  the alpha cut (α – cut) represented as



The strong α -cut 

The α -cut set is a crisp set. This threshold cut restricts the domain of the fuzzy set. Two main reasons why α-cuts are important are (i) The alpha level set describes a power or strength that is used by fuzzy models to decide whether or not a truth value should be considered equivalent to zero. This is a facility that controls the execution of fuzzy rules as well as intersection of multiple fuzzy sets, (ii) the strong α-cut at zero defines the support set for a fuzzy set. Figure 2.1 illustrates the regions in the universe compromising the core, support, crossover points and alpha cut of a typical fuzzy set.



**2.1.2 Convex fuzzy set**

A convex fuzzy set is defined as an enrollment work fuzzy set A whose qualities are carefully monotonically increasing, or whose participation esteems are carefully monotonically decreasing or whose enrollment esteems are carefully monotonically increasing then carefully monotonically decreasing with increasing qualities for components known to mankind. Fig 1.2 represents a convex and a non convex fuzzy set.

In other words for x, y, z in the fuzzy set A with x<y<z implies

 min[,] then A is said to be a convex fuzzy set.





(a)

(b)

**Figure: 2.2 (a) Convex, (b) Non convex**

**2.1.3 Representation of fuzzy set:**

The method of identifying fuzzy attributes and drafting the fuzzy set is an important technique. While dealing with uncertainties, decision makers are commonly provided, with information described by dubious etymological portrayals, for example, "generally safe", "high benefit", "high yearly loan cost" and so on. The goal of fuzzy set hypothesis is essentially worried about the evaluation of such ambiguous portrayals. The more the item fits the obscure predicate, the bigger is its evaluation of enrollment. The membership function may be viewed as representing an opinion poll of human thought or an expert’s opinion.

**2.2 FUZZY NUMBERS**

A fuzzy number A is a fuzzy set in real line which satisfies the conditions of both convexity and normality. In the literature most of the fuzzy sets use to satisfy the conditions of normality and convexity. Therefore fuzzy numbers are considered to be the most basic type of fuzzy sets.

A fuzzy set on the set of real number R is defined to fuzzy number if the membership functions : R  [0, 1] satisfy the following properties:

1.  Must be a normal set.
2. There exists at least one xR with 
3.  Is piecewise continuous

4

6

2

4

7

9

x

x

x

x

5

2

5

7

Figure 2.3 Real Number and Fuzzy Number

(a)

(b)

(c)

(d)









A fuzzy number (fuzzy set) represents a real number interval whose boundary is fuzzy. Membership functions of fuzzy numbers need be symmetrical. Fuzzy sets can have a variety of shapes. However, a triangle or a trapezoid often provides an adequate representation of the expert knowledge, simultaneously simplifying the process of computation to a significant level. So the triangular and trapezoidal shapes of membership functions are used most often for representing fuzzy numbers.

Special cases of real numbers include ordinary real numbers and interval of real numbers. Fig 1.3 (a) is a real number 5, Fig 1.3 (c) is a closed interval [2,7], Fig 1.3 (b) and Fig 1.3 (d) are a triangular fuzzy number and a trapezoidal fuzzy number expressing the concept “numbers close to 5”, respectively.

**2.2.1 Triangular fuzzy number**



1

0

a

b

c

x

Figure 2.4 Triangular Fuzzy Number

A Triangular Fuzzy Number can be defined by a triplet (a, b, c) (with a<b<c) whose membership function are given by



**2.2.2 Trapezoidal Fuzzy Number**

A Trapezoidal Fuzzy Number (TFN) is a fuzzy number (a, b, c, d) ( with a<b<c<d)and its membership function is defined by





1

0

a

b

c

d

x

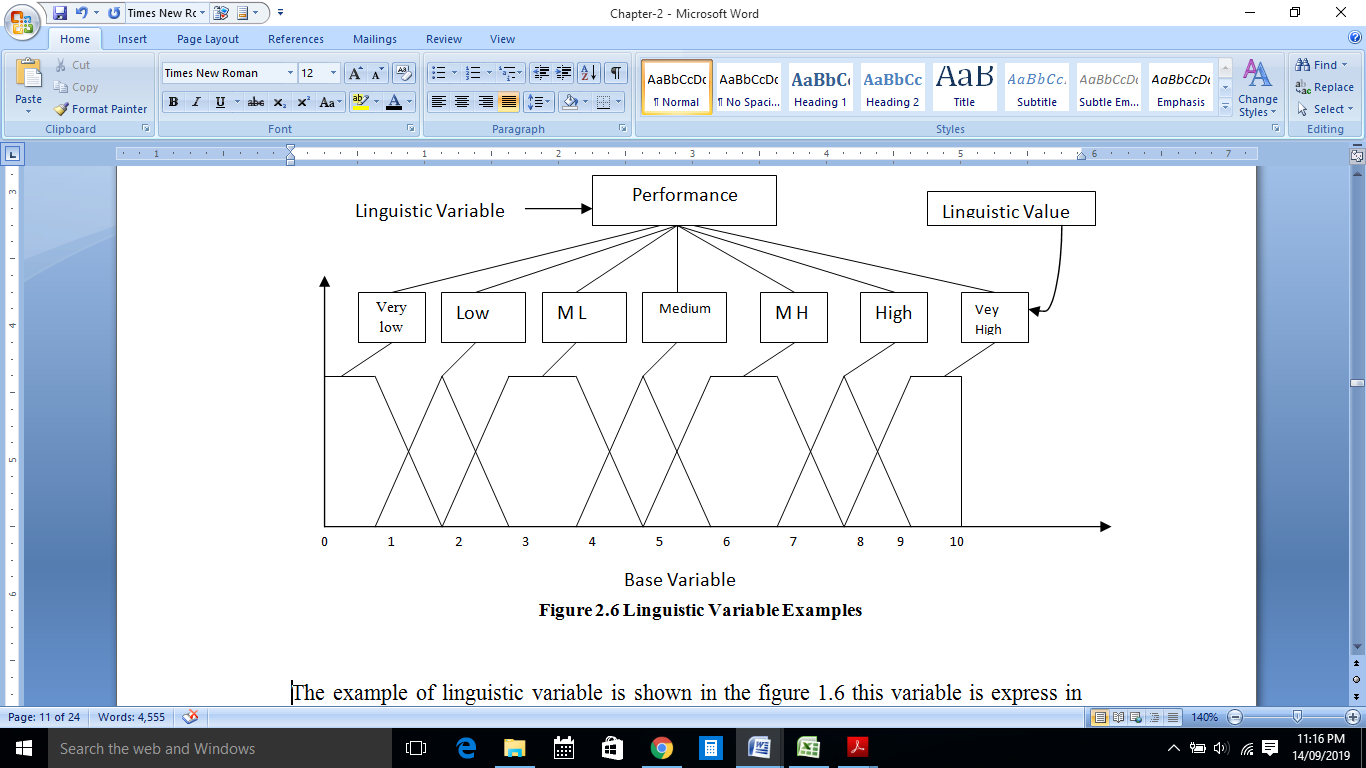
**Figure 2.5 Trapezoidal Fuzzy Number**

Although the triangular and trapezoidal shapes of membership function are used most often for representing fuzzy numbers, other shapes like bell shapes may be used in other applications.

**2.3 LINGUISTIC VARIABLES**

The idea of a fuzzy number assumes an essential job in detailing quantitative fuzzy variables. Fuzzy variables are variable whose details are fuzzy numbers. When likewise the fuzzy numbers representing linguistic ideas, for example, exceptionally small, small, and medium, etc, as translated in a specific idea, the subsequent developments are normally called linguistic variables.

Each linguistic variables, the conditions of which are communicated by linguistic term deciphered as a particular fuzzy numbers is defined in terms of base variable, the estimation of which are real number inside which a specific range. A base variable is a variable in the old style sense exemplified by any physical variable ( for example temperature, Pressure, Speed and so on) just as some other numerical variable ( for example Age, execution, compensation, stature and so on.) in linguistic variable phonetic terms speaking to surmised estimation of base variable, are capture by approximate suitable fuzzy numbers.

The example of linguistic variable is shown in the figure 1.6 this variable is express in the form of performance of a goal entity. The entity is given in the base variable i.e seven linguistic term very low, low , medium low, Medium, Medium high, High, Very High. Each of the linguistic term is assigned by one of the seven fuzzy number defined by figure 1.6 the fuzzy number whose membership value have the trapezoidal shape are defined by the interval [1, 10]

**2.4 OVERVIEW OF DECISION MAKING AND ITS SUPPORT**

The life of each person is filled with alternatives. From the moment of conscious thought to a venerable age, from morning awakening to nightly sleeping, a person meets the need to make a decision of some sort. This necessity is associated with the fact that any situation may have two or more mutually exclusive alternatives and it is necessary to choose one among them. The process of decision-making, in the majority of cases, consists of the evaluation of alternatives and the choice of the most preferable from them. Making the “correct” decision means choosing such an alternative from a possible set of alternatives, in which, by considering all the diversified factors and contradictory requirements, an overall value will be optimized (Pospelov and Pushkin, 1972); that is, it will be favorable to achieving the goal sought to the maximal degree possible

**2.4.1 Fuzzy Multi criteria Decision-Making:**

Models, Methods and Applications If the diverse alternatives, met by a person, are considered as some set, then this set usually includes at least three intersecting subsets of alternatives related to personal life, social life, and professional life. The examples include, for instance, deciding where to study, where to work, how to spend time on a weekend, who to elect, and so on. At the same time, if we speak about any organization, it encounters a number of goals and achieves these goals through the use of diverse types of resources (material, energy, financial, human, etc.) and the performance of managerial functions such as organizing, planning, operating, controlling, and so on, To carry out these functions, managers engage in a continuous decision-making process. Since each decision implies a reasonable and justifiable choice made among diverse alternatives, the manager can be called a decision maker (DM). DMs can be managers or expert at various levels, from a technological process manager to a chief executive officer of a large company, and their decision problems can vary in nature. Furthermore, decisions can be made by individuals or groups (individual decisions are usually made at lower managerial levels and in small organizations and group decisions are usually made at high managerial levels and in large organizations). The examples include, for instance, deciding what to buy, when to buy, when to visit a place, who to employ, and so on. These problems can concern logistics management, customer relationship management, marketing, and production planning.

**2.4.2 Decision making in a fuzzy environment**:

Making a decision is defined as the process of choosing alternatives to archive a goal. There are three distinct stages in the process of selection among available alternatives..

**2.4.3 Classification of MCDM:**

Since the 1960s, numbers of MCDM techniques have been created and used to describe a set of technique that can be applied by considering different criteria for the most part; they can be characterized into the accompanying groups (Hajkowicz and Collins, 2007):

1. Multi-attribute utility and value functions: the objective of these techniques is to characterize an articulation for the decision maker’s inclinations using utility/esteem capacities. In light of this, all criteria are changed into a typical dimensionless scale (Linkov et al., 2004). Mainstream techniques incorporate MAUT (multi-attribute utility theory) and MAVT (multi-attribute esteem theory), which have a compensatory nature. This infers the lackluster showing of one foundation (for example high loss of lives) can be remunerated by the better execution of another (for example money related expense). In spite of the fact that MAUT and MAVT have entrenched hypothetical establishments, the inclination elicitation can be psychologically testing and tedious (Schuwirth et al., 2012);

2. Pairwise comparisons: this methodology includes contrasting sets of criteria by asking the amount more significant one is than the other as indicated by a predefined scale. Pairwise comparisons are especially important when it is absurd to expect to characterize utility capacities. Basic procedures incorporate AHP (analytic hierarchy process), ANP (analytic network process) and MACBETH (measuring attractiveness by a categorical based evaluation technique). Because of its effortlessness and adaptability, AHP is the most useful MCDM tool. Nevertheless, AHP has a constraint when managing reliance among the criteria as it accepts that they are autonomous (Li et al., 2011). In addition, only a limited number of alternatives can be considered at the same time;

3. Distance to ideal point methods: the alternatives are assessed and ordered based on their distance from the ideal point, which represents a supposed alternative that best suits the decision makers’ objectives.

**2.5 METHODS**

**2.5.1 Fuzzy Analytic Hierarchy Process**

AHP was developed in 1980 and since then it has been commonly used in various decision making situations. The quality of AHP are (1) viewing a unpredictable problem as a simple hierarchical structure with alternatives and decision attributes, (2) having the capability of recognizing the relative weight of the factors and the total values of each alternative weight in multiple attribute problems based on using a series of pairwise comparisons, and (3) calculating the consistency index (CI) of pairwise comparisons, which is the ratio of the decision makers DM’s inconsistency. Since the real world is full of ambiguity and vagueness, orthodox MCDM cannot handle problems with imprecise information. In addition, incorporation of imprecise information and vagueness is an unavoidable requirement of fine multi criteria decision-making models. MCDM techniques need to tolerate vagueness; however, conventional MCDM, like traditional AHP, does not contain uncertainty in its pair wise comparisons (Yu, 2002). To deal with this kind of problem, Zadeh (1965) proposed using fuzzy set theory for complicated systems that are hard to define. Thus, fuzzy multiple criteria decision-making (FMCDM) was developed. As mentioned earlier, in decision-making, there is a fuzzy concept in comparisons as well. That is why there are many FAHP methods that are proposed by different authors in the literature ( Buckley, 1985; Chang, 1996; Cheng, 1997; Deng, 1999; Mikhailov, 2004; Van Laarhoven al et., 1983). Furthermore, it is easier to know and can effectively handle both qualitative and quantitative data (Liao, 2011). In this study, the FAHP approach that was introduced by Chang (1996) was preferred. In his approach, for the pairwise comparison scale, triangular fuzzy numbers (TFNs) can be used. This is simpler and needs less complicated calculations compared with other proposed FAHP methods.

**2.5.1 Chang 1996 Extent Analysis Method**

The extent analysis method proposed by Chang (1996) has been widely used to obtain scrip weights from a fuzzy comparison matrix. In the method, every criteria or alternative is evaluated by linguistic variables and then the extent analysis is performed.

The algorithm of the extent analysis method can be summarized as follows:

**Step 1**: The pairwise comparison matrix is a set as follows:

(2.1)

Where i, j =1,2, …, n and all , i, j =1, 2, …, n are triangular fuzzy numbers.

**Step 2**: The value of fuzzy synthetic extent with respect to the criteria Si is defined as

(2.2)

In the equation (2.1) and are calculated by using the fuzzy addition operation of n extent analysis for a fuzzy pairwise comparison matrix as follows:

The principles for the comparison of fuzzy numbers were introduced to get the weight vectors of all essentials for each level of hierarchy with the use of fuzzy synthetic values.

**Step 3:** To compare the fuzzy numbers, the degree of possibility of M2≥M1 is calculated as

Where M1 = (l1, m1, u1) and M2 = (l2, m2, u2) and d is the ordinate of the highest intersection point D between To compare M1 and M2, both V(M2≥M1) and V(M1≥M2) are needed

Step 4: The degree of possibility for a fuzzy number to be greater than k fuzzy number Si (i=1,2,…,k) can be defined by

*M1*

*M2*

*D*

*µM*

*1*

*M*

*0*

*l1*

*m1*

*l2*

*d*

*m2*

*u2*

*u1*

*V(M2≥M1)*

**Figure 2.7** the intersection between M1 and M2

Assume that

, i, k=1,2,…,n: k (2.6)

Then, the weight vector is given by

(2.7)

Step 5: Via normalization, the normalized non fuzzy weight vector is computed as

**2.5.2 Fuzzy TOPSIS**

Chen (2000) and Li (2007) extended The Order Preference by Similarity to Ideal Solution (TOPSIS) method to present methods that handles fuzzy multi- criteria group decision making problems under fuzzy environment. Consider that there are k decision- makers DM1, DM2, …, DMk. m alternatives and n criteria C1, C2, …, Cn. Chen’s method of fuzzy multi criteria-decision making is reviews as follows:

**Step 1**: The decision makers apply the linguistic variable to evaluate the importance of the criteria

**Step 2**: The decision-makers apply the linguistic rating variables to estimate the rating of the alternatives with respect to each criteria.

**Step 3**: Convert the linguistic evaluation into triangular fuzzy numbers to construct the fuzzy decision matrix

(2.16)

Where, denotes the rating of the pth decision maker with respect to criteria Cj to the alternatives , where 1p≤k, 1≤j≤m and 1≤j≤n. Construct fuzzy weighting vector W, shown as follows:

(2.17)

Where the weight of criteria Ci is denoted by, that is , denotes the importance weight of decision maker DMp with respect to Ci where 1p≤k, 1≤j≤n.

**Step 4:** Construct the normalized fuzzy decision matrix

, (2.18)

where 1i≤m, 1≤j≤n.

**Step 5**: Construct the weighted standardized fuzzy decision network

, (2.19)

where and indicates the multiplicative administrator between fuzzy numbers.

**Step 6:** Determine the fuzzy positive perfect arrangement and fuzzy negative ideal solution , where ) and )

**Step 7**: Calculate the distance between the option between the other option

and the fuzzy positive ideal solution where 1≤i≤m. Calculate the distance between the alternative and the fuzzy negative ideal solution where 1≤ i ≤ m, shown as follows:

Where means the separation between elective and the fuzzy positive perfect arrangement Where indicates the separation between elective and the fuzzy negative ideal solution denotes the distance between the fuzzy numbers and, denotes the distance between the fuzzy numbers and, 1≤ i ≤ m and 1≤ j ≤ n

**Step 8**: Calculate the closeness coefficient CCi of alternative,

where 1≤ i ≤ m, shown as follows:

, (2.22)

Where signifies the separation between elective and the fuzzy positive perfect arrangement, denotes the distance between alternative and the fuzzy negative ideal solution , 1≤ i ≤m.

**Step 9**: : Based on the closeness coefficient of every option determined in Step 8, the ranking request of the options is obtained. The bigger the estimation of the closeness coefficient CCi of alternative, 1≤ i ≤m.

Chapter -3

STUDY AREA AND DATA COLLECTION

**3.1 INTRODUCTION**

**3.2 GEOGRAPHY OF STUDY AREA**

**3.3 RIVER BASIN OF BTAD**

**3.4 DATA COLLECTION**

* 1. **INTRODUCTION**

This chapter gives a description of the study area, administrative structure, pupation, River basin, and the secondary data collected from different sources for the study and analysis of the present work. There are about more than 49 numbers of big and small River basin of most of which are originates from the Himalaya that is the Bhutan Hills

* 1. **GEOGRAPHY OF STUDY AREA**

The Bodoland Territorial Council (BTC) is a regional board built up ia assam state via cutting out certain territories of eight regions of Assam to be specific Kokrajhar, Dhubri, Bongaigaon, Barpeta, Nalbari, Kamrup, Darrang, and Sonitpur inside the stateof Assam. The territory under the BTC purview is known as the Bodoland Territorial Area District (BTAD). It is a self-governing Administrtive Unit established under the Sixth Schedule of the constitution of India covering a zone of 8851 (Provisional). The BTAD comprise of four coterminous regions in particular kokrajhar, Chirang, Baksa and Udalguri. The topographical Boundary of BTAD lies between 26° 7'12'' N to 26° 7'50'' N scope and 89° 47'40'' E to 92° 18'30'' E longitude and it is the north-western piece of Assam. Kokrajhar town the managerial head quarter lies between 26° 25' N longitude and 99° 16'38'' E latitude. BTAD is situated on the north bank of Brahmaputra waterway in Assam in the North-East India by the lower regions of Bhutan and Arunachal Pradesh. The district is hindered dominatingly by Bodo language talking ethnic gathering and Bengalis, Assamese, Rabha, Rajbongshi, Garo, and different indigenous Mongoloid clans blessed with natural beauty withlivers and vast forests covers and abundant flora and fauna. It is located in the foothills of Bhutan and barderining North Bengal .Administrative Structure of the study area is shown in the table 3.1.

Table 3.1

Administrative structure of BTAD

|  |  |  |
| --- | --- | --- |
| **Name District** | **Name of Sub-Division** | **Name of Revenue circles (R.C)** |
| Kokrajhar | Kokrajhar(HQ) | (5 -R. C.)Kokrajhar, Dotma, Bhowraguri, Gossaigaon and Bagribari |
| Gossaigaon |
| Parbatjhora |
| Chirang | Kajolgaon(HQ) | (6-R.C.) Kokrajhar (Pt), Bengtol, Sidli(Pt), Bongaigaon(Pt), Bijni(Pt) and Barnagar(Pt) |
| Bijni |
| Baksa | Mushalpur(HQ) | (13-R C)  Baska, Barama, Tamulpur , Goreswar, Baganpara , Ghograpar, Barnagar , Bajali, Jalah , Patharighat, Rangia Sarupeta , Tihu |
| Tamulpur |
| Salbari |
| Udalguri | Udalguri(HQ) | (9-R.C) Udalguri , Mazbat, Harisinga Kalaigaon, Khoirabari ,Dalgaon  Patharighat, Mangaldoi , Dhekiajuli |
| Bhergaon |

**3.2.1 Population**

The total population of the study area is 31, 51,047 with a density of 325 per sq. km. The male population is 50.8 % to total population and the percentage of female population is 49.2% .The sex ratio of this area is 968 per thousand male according to 2011 Census. The no. of females per thousand males is increasing in the study area. Male population is greater than female population in most of the districts of the study area. The lowest sex ratio is 959, which is observed in Kokrajhr and the highest sex ratio is 974 in Baksa. The main economic activity of this area is agriculture. But flooding is a recurrent problem in this area. Hence, almost each and every year agriculture is greatly damaged by flood. Here flooding is a push factor for migration. Male persons migrate for job in other states as they lose their job opportunity.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Table 3.2. | | | | | | |
| Demographic structure in BTAD region | | | | | | |
| District | Male | Female | Total | Area sq km | Density | Sex ratio/1000 |
| Kokrajhar | 452905 | 434237 | 887142 | 3296 | 269 | 956 |
| Chirang | 244860 | 237302 | 482162 | 1923 | 251 | 969 |
| Baksa | 481330 | 468745 | 950075 | 2457 | 387 | 974 |
| Udalguri | 421617 | 410051 | 831668 | 2012 | 413 | 973 |
| Total | 1600712 | 1550335 | 3151047 | 9688 | 325 | 968 |
| **Source:** Census Handbook, Four District-2011 | | | | | | |

3.2.2 **Climate**

The climate of BTAD has sub-tropical with hot summer and cold winter. Humid hot summer with high humidity (75% to 80%), monsoon rainfall dry winter and dust storm during the months of February to April are some of typical characteristics of the climate of the study area.

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 average temperature during the pre monsoon summer season is about 28.5 ͦC with relative humidity 75%, associated with occasional thunderstorm. Most of the rainfall (80%) occurs due to the onset of summer monsoon (May to August). The annual rainfall varies from 1600mm to 2680 mm. The winter is really comfortable. Its temperature varies between 10 ͦC to 17 ͦC. Heavy fogs sometimes occur during the winter season. Heavy rainfall during the months of June and late August is the important factor of flood

District wise rainfall of BTAD for last three years shown in the table 3.3, 3.4, 3.5

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 3.3 | | | | | | | | | | | |
| District wise Rainfall BTAD 2014 | | | | | | | | | | | |
| Month | Kokrajhar | | Chirang | | Baksa | | | Udalguri | | Total | |
| 1 | 2 | 3 | 4 | 5 | 6 | | 7 | 8 | 9 | 10 | 11 |
|  | Normal mm | Actual mm | Normal mm | Actual mm | Normal mm | Actual mm | | Normal mm | Actual mm | Normal mm | Actual mm |
| January | 11.04 | - | 5.64 | - | 15.20 | 14.50 | | 2.00 | - | 33.88 | 14.50 |
| February | 21.46 | 51.40 | 13.33 | 66.31 | 35.00 | 30.60 | | 2.00 | - | 71.79 | 148.31 |
| March | 76.29 | 13.60 | 39.46 | 35.40 | 52.20 | 70.70 | | - | - | 167.95 | 119.70 |
| April | 223.52 | 25.90 | 202.62 | 651.55 | 147.20 | 140.00 | | 2.20 | 75.00 | 575.54 | 892.45 |
| May | 470.41 | 554.60 | 462.21 | 1261.30 | 234.00 | 227.30 | | 2.00 | 200.00 | 1168.62 | 2243.20 |
| June | 899.70 | 847.80 | 475.54 | 847.80 | 570.20 | 298.20 | | 300.00 | 437.00 | 2245.44 | 2430.80 |
| July | 585.54 | 377.50 | 448.98 | 1239.44 | 721.00 | 297.30 | | 290.00 | 443.00 | 2045.52 | 2357.24 |
| August | 622.35 | 804.10 | 320.09 | 941.24 | 531.51 | 265.30 | | 340.00 | 267.75 | 1813.95 | 2278.39 |
| September | 430.60 | 360.40 | 250.61 | 451.47 | 273.87 | 180.50 | | 140.00 | 134.00 | 1095.08 | 1126.37 |
| October | 189.20 | 3.40 | 65.43 | 39.89 | 133.70 | 150.00 | | 30.00 | 28.75 | 418.33 | 222.04 |
| November | 5.11 | - | 6.68 |  | 28.20 | 18.70 | | 20.00 | 5.00 | 59.99 | 23.70 |
| December | 2.42 | 2.40 | 1.44 |  | 10.70 | 9.20 | |  |  | 14.56 | 11.60 |
| Source: Statistical Hand Book of BTC | | | | | | | | |  | 9710.65 | 11868.30 |

Figure 3.1 Year round rainfall of BTAD, 2014

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table-3.4 | | | | | | | | | | |
| District wise Rainfall BTAD 2015 | | | | | | | | | | |
| Month | Kokrajhar | | Chirang | | Baksa | | Udalguri | | Total | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|  | Normal mm | Actual mm | Normal mm | Actual mm | Normal mm | Actual mm | Normal mm | Actual mm | Normal mm | Actual mm |
| January | 10.90 |  | 5.54 | 1.00 | 10.30 |  | 13.10 | 9.00 | 39.84 | 10.00 |
| February | 20.80 | - | 13.33 |  | 26.90 | 18.10 | 21.40 | 19.50 | 82.43 | 37.60 |
| March | 68.40 | 49.90 | 33.46 | 20.00 | 54.00 | 43.10 | 53.50 | 17.00 | 209.36 | 130.00 |
| April | 23.40 | 22.10 | 202.60 | 61.10 | 175.70 | 301.50 | 168.80 | 245.50 | 570.50 | 630.20 |
| May | 507.40 | 682.70 | 462.21 | 577.00 | 391.50 | 182.40 | 320.00 | 382.00 | 1681.11 | 1824.10 |
| June | 750.60 | 905.10 | 475.54 | 1130.60 | 694.30 | 436.60 | 434.50 | 617.00 | 2354.94 | 3089.30 |
| July | 585.50 | 526.10 | 448.98 | 1441.00 | 757.30 | 519.80 | 345.00 | 260.00 | 2136.78 | 2746.90 |
| August | 631.70 | 674.70 | 340.00 | 466.00 | 527.30 | 416.20 | 271.20 | 794.00 | 1770.20 | 2350.90 |
| September | 430.06 | 154.20 | 250.61 | 344.00 | 462.10 | 209.70 | 221.50 | 246.00 | 1364.27 | 953.90 |
| October | 136.90 |  | 65.43 |  | 142.10 | 144.00 | 95.40 | 56.00 | 439.83 | 200.00 |
| November | 36.80 | 6.30 | 6.68 | 1.00 | 20.40 | 13.20 | 17.20 | 12.50 | 81.08 | 33.00 |
| December | 2.80 | 4.20 | 1.44 | 13.8 | 12.70 |  | 9.30 | 9.50 | 26.24 | 27.50 |
| Source: Statistical Hand Book of BTC | | | | | | | | | 10756.58 | 12033.40 |

Figure 3.2 Year round rainfall of BTAD, 2015

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 3.5 | | | | | | | | | | |
| District wise Rainfall BTAD 2016 | | | | | | | | | | |
| Month | Kokrajhar | | Chirang | | Baksa | | Udalguri | | Total | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|  | Normal mm | Actual mm | Normal mm | Actual mm | Normal mm | Actual mm | Normal mm | Actual mm | Normal mm | Actual mm |
| January | 9.41 |  | 5.54 | 1.00 | 10.30 |  | 13.10 | 9.00 | 38.35 | 10.00 |
| February | 19.20 | - | 9.94 | - | 26.90 | 21.10 | 21.40 | 21.50 | 77.44 | 42.60 |
| March | 75.60 | 73.60 | 37.70 | 53.43 | 54.00 | 120.40 | 53.50 | 24.20 | 220.80 | 271.63 |
| April | 262.90 | 354.50 | 197.49 | 483.12 | 175.70 | 122.50 | 169.50 | 340.40 | 805.59 | 1300.52 |
| May | 492.50 | 241.60 | 303.59 | 307.93 | 391.50 | 139.00 | 322.00 | 350.20 | 1509.59 | 1038.73 |
| June | 707.00 | 369.80 | 542.90 | 760.35 | 694.30 | 522.00 | 436.20 | 620.00 | 2380.40 | 2272.15 |
| July | 558.70 | 518.00 | 550.69 | 829.85 | 757.30 | 718.00 | 346.20 | 255.00 | 2212.89 | 2320.85 |
| August | 604.02 | 67.00 | 318.59 | 133.07 | 527.30 | 168.00 | 275.20 | 785.39 | 1725.11 | 1153.46 |
| September | 407.60 | 369.40 | 248.26 | 306.80 | 462.10 | 214.00 | 220.50 | 250.10 | 1338.46 | 1140.30 |
| October | 155.30 | 309.70 | 46.82 | 94.44 | 142.10 | 54.00 | 95.00 | 60.50 | 439.22 | 518.64 |
| November | 2.00 |  | 2.54 |  | 20.40 |  | 17.25 | 5.00 | 42.19 | 5.00 |
| December | 0.92 |  | 13.80 |  | 12.70 | 2.00 | 9.00 | 3.00 | 36.42 | 5.00 |
| Source: Statistical Hand Book of BTC | | | | | | | |  | 10826.46 | 10078.88 |

Figure 3.3 Year round rainfall of BTAD, 2016

**Figure 3.4:** Average yearly maximum and minimum temperature of BTAD recorded for the year 2014 to 2016

3.3 **RIVER BASIN OF BTAD**:

BTAD lies on the north Bank of the Brahmaputra River Basin. There are several no 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 and cause flood and erosion in various part of BTAD.

River system under the BTAD comprises of various tributaries and sub-tributaries are shown in the Figure 3.5 enlisted in the table 3.6

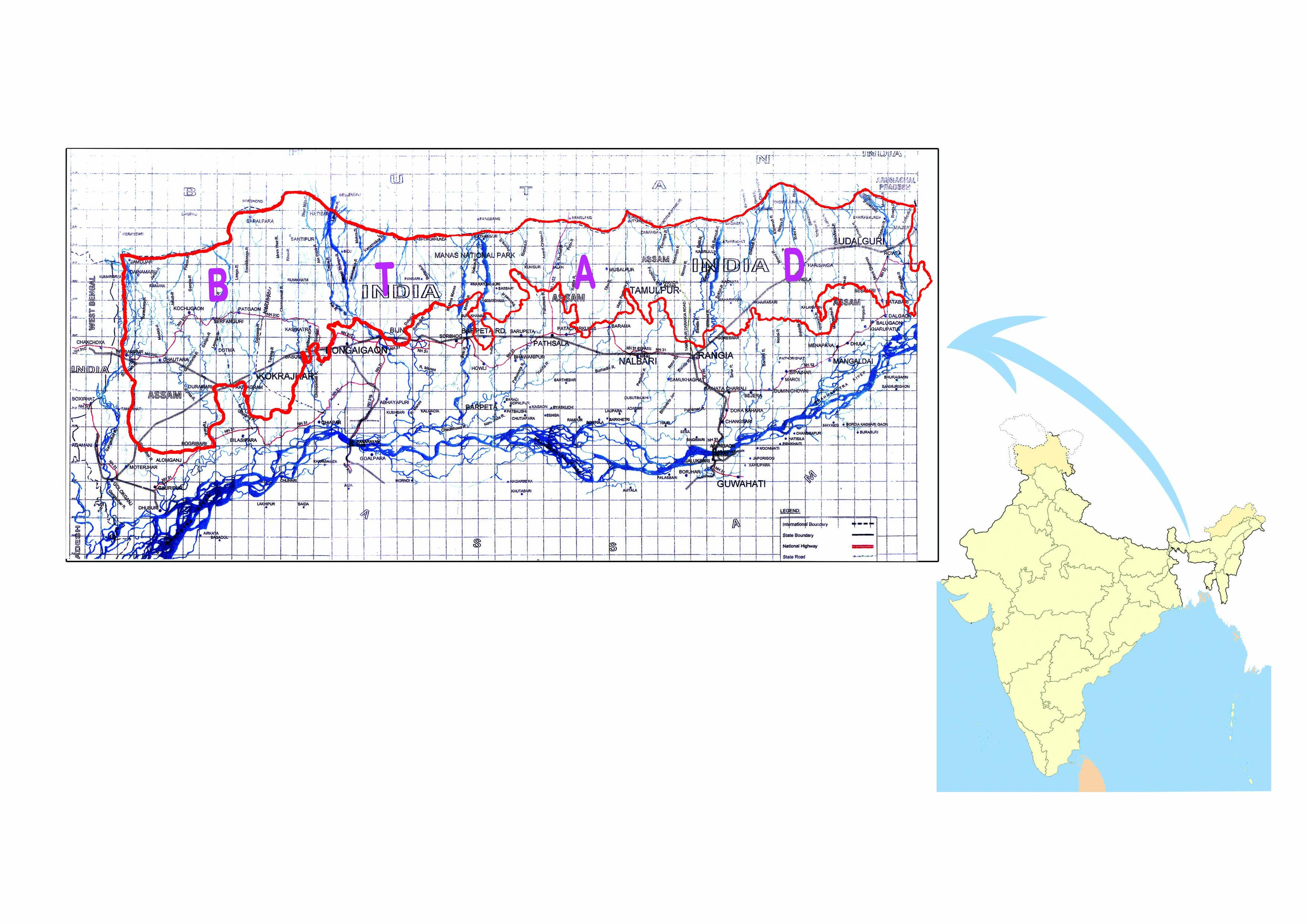


Figure 3.5 study area map

|  |  |  |
| --- | --- | --- |
| Table-3.6 | | |
| River system under BTAD | | |
| Sl. no. | Name of River | Category of river |
|  |  |  |
| 1 | 2 | 3 |
|  |  |  |
| 1 | Sankosh | B |
| 2 | Modati | D |
| 3 | Janali | D |
| 4 | Jakati | D |
| 5 | Pekua | D |
| 6 | Gangia | C |
| 7 | Garupehella | C |
| 8 | Joyma | C |
| 9 | Tipkai | B |
| 10 | Longa | C |
| 11 | Saralbhanga | B |
| 12 | Gaurang | B |
| 13 | Champabati | C |
| 14 | Tarrang | D |
| 15 | Burachara | C |
| 16 | Hel | D |
| 17 | Laksa | D |
| 18 | Aie | C |
| 19 | Taklai | C |
| 20 | Kanamaka | D |
| 21 | Dulani | C |
| 22 | Burisuti | D |
| 23 | Mara Manas | D |
| 24 | Manas | B |
| 25 | Hakua | D |
| 26 | Kalapani | D |
| 27 | Pahumara | C |
| 28 | Rupahi | C |
| 29 | Anguili | D |
| 30 | Kalda | D |
| 31 | Tihu river | C |
| 32 | Mara pagladia | D |
| 33 | Pagladia | C |
| 34 | Noonai | C |
| 35 | BaraLia | C |
| 36 | Phuthimari | B |
| 37 | Suklai | D |
| 38 | Barnadi | B |
| 39 | Nonoi | C |
| 40 | Kalanadi | C |
| 41 | kulsi | D |
| 42 | Bikhanti | D |
| 43 | Kalyani | D |
| 44 | Lakhi | D |
| 45 | Chans | C |
| 46 | Chandara | D |
| 47 | Mara Dhansiri | D |
| 48 | Dhansiri | C |
| 49 | Rawta | C |

Source: Water Resource Department, Assam

3.2.1 **River Sankosh Sub-Basin**: The River Sankosh originates from the snow clad mountain of greater Himalaya Ranges of Tibet at an elevation of about 7300 m above the mean sea level. The Sankosh sub-basin lies between latitude 25 ͦ43’ to 28 ͦ28’N and 89 ͦ34’ to 90 ͦ23’E. Out of total catchment area of 10345 sq km, 849 sq km lies in Assam and the 9496 sq km lies Bhutan. The River is known as Gangadhar after crossing NH 31c at Srirampur.

* + 1. **River Joyma (Garuphella) River sub-basin**: Originating from the lower reaches of Himalayan in Bhutan if flows through the forest land and inter populated area the river modati meets Garuphella after crossing NH 31C and takes the name joyma which again meets the Gangia at Sapatgram and then take the name Tipkai and ultimately outfalls into mighty Brahmaputra.
    2. **Giver Gangia River sub-basin**: The Hel after flowing from foothills of Bhutan enters BTAD, Assam and passes through the Ripu reserved forest in braided pattern and crosses NH 31C at Serfanguri, it starts meandering and flows through the populated area ultimately meets the river Joyma.
    3. **River Saralbhanga-Gaurang** – Samukha sub-basin: The river Saralbhanga originates from the Bhutan foothills and travels through the Kashugaon forest and enters into the plain area meet with Gaurang at Mogormari 7km upstream of Kokrajhar town and ultimately outfalls into river Brahmaputra.
    4. **River Champamati sub-basin:** The river Champamati originating from the Bhutan hills and traversing through the Bhutan territory where it is known as Bhur, it enters in kokrajhar district taking two names Dhalpani and Laopani , again joint together takes the name Champamati and outfalls into Brahmaputra near at Chapar town.
    5. **River Manas- Beki- Aie sub basin**: It is one of the biggest and important sub-basin of the Brahmaputra river basin. The sub basin lies between altitude 26 ͦ15’ N to 28 ͦ40’N and longitude 90 ͦ13’E to 92 ͦ18’E. The catchment area lies in Tibet, Bhutan, and India.

The entire river system of the sub basin may be divided into three group of river system (i) Aie river system (ii) Beki-manas river system

1. Aie river system: Aie river, which originates in the Black mountain of Bhutan at an altitude of about 4915 meters near the village of Bangpani, is about 110 km. The Aie river is heavily braided in nature with marked with characteristic braided channels and frequent changes of course. It carries a huge of sediment during flood and continuous erodes its banks thereby causing threat to thousands of inhabitants and hundreds of villages nearby. The entire course of river Aie has been experiencing the natural process of self adjustment of its section and parameters. Active erosion and inundation are found in the above mentioned areas also adjoining area for last 20 years. The river ultimately outfalls on the Brahmaputra.
2. **Beki-Manas River:** Originating from Bhutan foot hills it meets the Tongsa river before interring in India. It enters in India (BTAD) at Mathanguri and divided into three rivers namely Mora manas, Hahua ans Manas rivers, all the rivers then flow through the Manas National Park and enters the populated area again meets together near Barpeta Road and then takes the name Beki river. The other rivers in these basin area are Dulani and Burisuti. Chawlkhowa river basin area does not fall under BTAD.
   * 1. **River Pahumara**- Pagladia sub basin: originating from Bhutan river pomara, river rupahi river, thebor river and Anguli river meets and takes the name Pahumara river. The other rivers in this sub basin are tihu river , Mora Pgladia and Pagladia river.
     2. **River Phutimari**- Suklai-barnadi sub basin: All these rivers are originating from Bhutan foot hills and important sub basin of Brahmaputra river basin.
     3. **River Dhansiri sub basin**: originating from Bhutan and then passing through Arunachal Pradesh it inters through Bhairubkunda into Udalguri, BTAD . The other rivers in this basin area are Rowta river, Lalnadi, Mora dhansiri Golanadi etc.

Most of all these river during the flood season become flashy, cause flood and erosion in various parts of BTAD.

* 1. **DATA COLLECTION**

The required data for this study are under hydrology (environmental), Social, economical components. The hydrological (environmental) data are collected from the water resources department Assam, population data from National census, govt. of India 2011, economics data from statistical hand book BTAD, Dailly flood report from Assam Disaster management Assam Flood reports from Deputy commissioners’ offices from BTAD and experts opinion through the technical meeting and discussion.

Chapter -4

IDENTIFICATION OF THE FLOOD VULNERABILITY

**Fuzzy VIKOR approach to identify the flood vulnerability river basin region**

**4.1 INTRODUCTION**

**4.2 THE OWA OPERATOR**

**4.3 THE PROPOSED VIKOR METHOD**

**4.4 THE CASE STUDY OF PROPOSED METHOD**

**4.5 RESULT AND DISCUSION**

**4.6 CONCLUSION**

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1. **INTRODUCTION:**

In this chapter, we are interested to investigate the flood vulnerability region in BTAD of Kokrajhar, Assam, India by applying Fuzzy VIKOR Method, which was developed for multi- criteria optimization for complex system, to find a compromise priority alternative from selected criteria for flood vulnerability assessment.

The rest of this chapter has been organized as follows, in section 4.2. OWA operator. In section 4.3, we propose the fuzzy VIKOR based MCDM method for group decision making to investigate flood vulnerability under fuzzy environment. A case study is provided in section 4.4 to demonstrate the proposed method, section 4.5 result and discussion and some conclusions are made is section 4.6 finally.

**4.2 THE OWA OPERATOR**

**4.2.1 The Ordered Weighted Averaging (OWA)**

(Yager, 1988) first introduced the OWA Ordered Weighted aggregation for aggregating multi criteria to form over all decision function. The advantage of OWA is that the input data is rearranged in descending order and the loads related with the OWA administrator are the loads of the arranged places of the info information instead of the loads of the info information the weights associated with the OWA operator are the weights of the ordered positions of the input data rather than the weights of the input data (Lui, 2013).

**Definition:** An OWA operator of dimension n is a mapping OWA: Rn R that has an associated weighting vector , such that:

OWA (4.1)

Where bj is the jth largest of the ai .

The OWA operator is commutative, monotonic, bounded and idempotent. (Lui, 2015)

1. **Determination of OWA Weights**

(Yager , 1988; Xu, 2005) suggested a normal distribution based method for generating the OWA weights operator (Lui, 2013)by this method, the associated weighting vector is obtained by

, (4.2)

Where ω is the weight vector of the OWA operator, is the mean of the collection 1, 2, ..., n , is the standard deviation of 1,2, ... n. can be obtained by the following formulas, respectively:

(4.3)

(4.4)

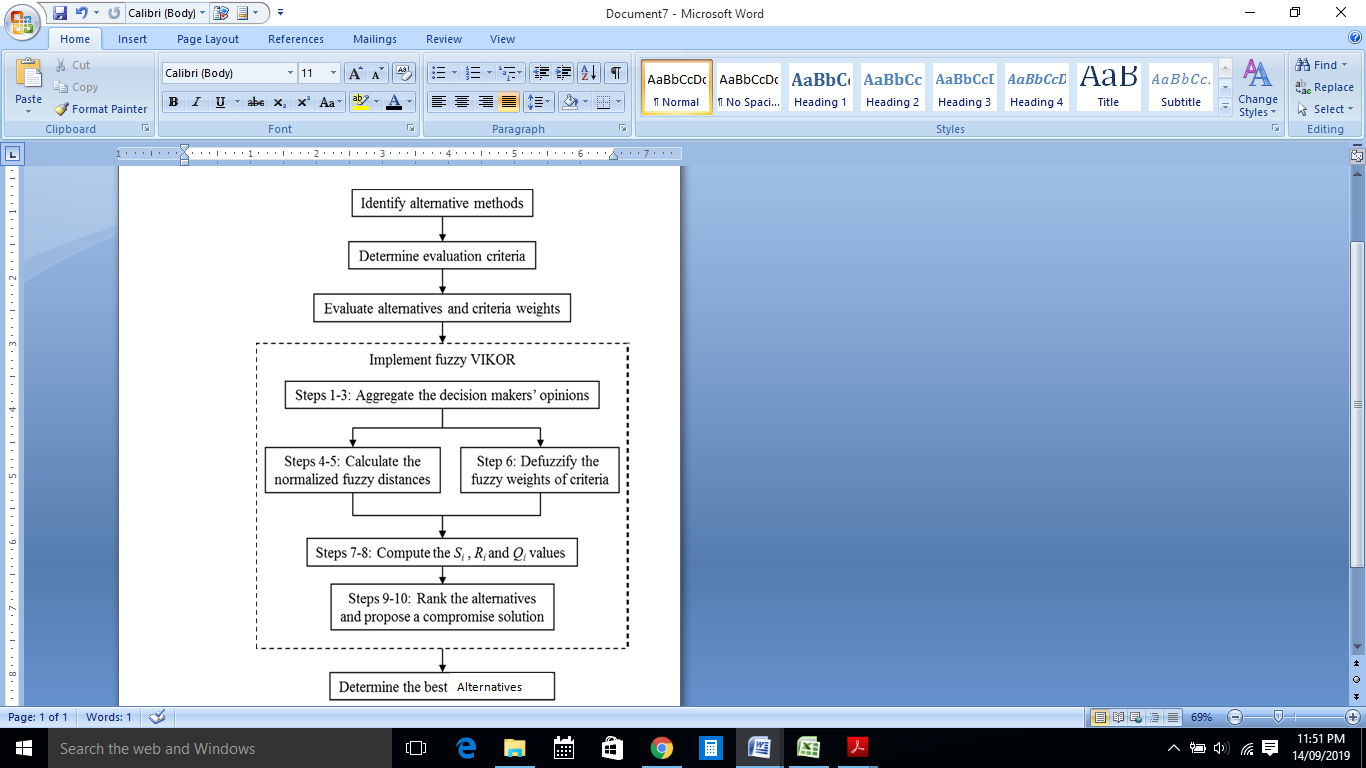


Figure. 4.1 Flowchart of the best alternative selection process

* 1. **THE PROPOSED VIKOR METHOD**:

In this section we are going to use extended version of Fuzzy VIKOR Method suggested by (Opricovic, 2011) It is focused on finding the best alternatives and a compromise solution of conflict criterion problems are determined. Let Ai (i=1,2, ...,n) be finite set of n alternatives which to be evaluated by L experts Ek (k=1,2, ...,L) with respect to a set of m evaluated criteria Cj (j=1,2, ...,m). The Fuzzy VIKOR procedure consists of the following steps as stated by (Lui, 2013; Yucenur et al., 2012)

**Step-1**: Construct the judgment matrix and weight vector that denote the fuzzy assessments matching to qualitative criteria for each decision-maker, and the importance weights of criteria.

**Step-2:** The OWA weights for the decisions makers are computed as suggested by (Xu.,2005) The normal distribution based method is employed (Lui, 2015) to calculate the weight of the OWA operator. By this method, the associated vector weight can be obtained by Eqns. 4.9- Eqn-4.12. For example, if n=6 the we get  =3.5 and  = we get OWA weight values as w = (0.0865, 0.1716, 0.2419, 0.2419, 0.1716, 0.0865)T

**Step-3**: Aggregate the decisions makers’ (experts’) opinion to construct a fuzzy decision matrix and get the aggregated fuzzy weights of criteria.

Let the Fuzzy rating for ith alternative regarding jth criterion of lth experts be  And  (i=1,2,...m) and (j=1,2,...n) restively Hence the aggregated fuzzy rating of alternatives with respect to each criteria can be calculated by using Eqn-4.9

 (4.5)

Similarly the aggregated fuzzy weights  of each criterion can be calculated as 

Thus the matrix  and the weight  could be expressed as

  (4.6)

**Step-4**: Determine the best and worst value of all criterion rating

(4.7)

(4.8)

**Step-5**: Calculate the normalized fuzzy distance  , i=1,2, ...m, j=1,2,...n

(4.9)

**Step -6**: Defuzzify the fuzzy weight of each criterion into crisp values

The aggregated trapezoidal fuzzy number  where the defuzzified to the best non fuzzy performance value  on the centroid of TFN () is calculated by using following equation



(4.10)

 **Step-7:** Calculate the value of Si and Ri as follows i-1,2,.....m

 (4.11)

 (4.12)

Where are the weights of the criteria, Si and Ri represents the utility measure and regret measure.

**Step-8**: Calculate the value of  and 

(4.13)

**Step-9** Rank the alternative by sorting the value of S, R, and Q ascending order.

**Step-10**: Propose a trade off arrangement the option A(1) , which is the best positioned arrangement by the measure Q(minimum) if the following two conditions are fulfilled.

C1. "Acceptance advantage:

Where A(2) with second position in the ranking rundown by Q and DQ=1/m-1

C2. Acceptable stability in decision making

The option A(1) should likewise be the best position by S or R. This trade off arrangement is steady within a decision making process which could be system of most extreme gathering utility (when v > 0.5 is required) or "by agreement" or "with veto v <0.5

Subsequently v is the heaviness of decision making system of most extreme gathering utility.

On the off chance that one of the conditions isn't fulfilled, at that point the trade off arrangement is proposed which comprise of -

CS1. Alternatives A(1) and A(2) if just the condition C2 isn't fulfilled

Or on the other hand

CS2. Alternatives A(1), A(2), ... A(m) if the condition C1 isn't fulfilled: A(m) is determined by the connection for most extreme M ( The situation of these options are "in closeness")

The VIKOR technique is a viable device in multi criteria decision making. The obtained trade off arrangement could be acknowledged by the decision creators since it gives a greatest gathering utility of the ''lion's share'' (spoke to by min S, Eq. (4.20), and a minimum individual lament of the ''rival'' (spoke to by min R, Eq. (4.19). The VIKOR calculation can be performed without interactive cooperation of DM, however the DM is responsible for approving the final arrangement and his/her inclination must be included. The trade off arrangements could be the base for exchange, involving the decision producers' inclination by criteria loads.

* 1. **THE CASE STUDY OF PROPOSED METHOD**
     1. **Study Area**

A case study was conducted in the river basin areas of Kokrajhar district of BTAD, Assam, India to illustrate the application of proposed Fuzzy VIKOR Method. The Kokrajhar district lies roughly between 89o46' to 90o38' east longitudes and between 26o19’ to 26o54' north latitudes. The region is limited on the north by the Himalayan Kingdom of Bhutan, by Dhubri area on the south, Chirang locale on the east and the interstate limit of West Bengal on the west.The major rivers in this district are Champamati, Gaurang (Sharalbhanga), Hell (Gongia), Guruphella, Tipkai and Sankosh. These major rivers mostly originate from the Bhutan hills which is the source and flows towards south through the district and act as tributaries of the mighty Brahmaputra that flows east to west far from the southern boundary of Kokrajhar district. The basin area is about 3,169 km2 and consists of three administrative sub-divisions, Kokrajhar, Gossaigaon and Parbathjhara, 9 no. of Circles, 11 no. of Blocks and around 941 villages. The area covers 51.63% forest land, 47.10% Agriculture land, .25% Build area and 0.48% water bodies 38 the region receives rainfall due to the influence of south west tropical monsoon during the period May to October. The average rainfall is between 2100-3600 mm annually. The area has a rapid population growth and some development plans can also be considered. For the last ten years there has been frequent damages caused flood. The flood left 29 people death and thousands homeless.

The most common hydrologic vulnerability is watershed approach, the study a reach-based areal approach based on river reach is used. The basin area is divided as per the main river basin including its stream. The district watershed basin is divided into five sub- basin region as follows:

A1: Sub basin1 (Champamati River basin)

A2; Sub basin2 (Gourang-Sharalbhanga River basin)

A3: Sub basin3 (Hel- Gongia River basin)

A4: Sub basin4 (Modati-Joyma-Tipkai River Basin

A5: Sub basin5 (Songkosh-Gadadhar River basin)

As the flood vulnerability is inherent in various circumstances, including the possibility of disaster, the influences of the disaster on society and society’s ability to respond to a disaster (Lee, 2013) To assess flood vulnerability, we consider various parts of the region such as (a) Environmental factor, (b) Social Factor, (d) Economic factors as criteria and their relevant sub criteria are identified as vulnerability criteria in a hierarchical structure as shown in fig 4. In request to find the most weakness area, a specialist board of trustees of six decision creators, E1, E2, E3, E4, E5 and E6 has been shaped. These specialists are from various offices one Sub Divisional Circle Officer (SDCO), one from District Disaster Management Authority (DDMA), two are official Engineers under the water asset department one from relief and rehabilitation office and one Assistant Professors.

Based on the literature, regarding the evaluation of flood vulnerability on the criteria and sub-criteria things were discussed with the experts.

The watershed basin is presented in the fig 4.2.

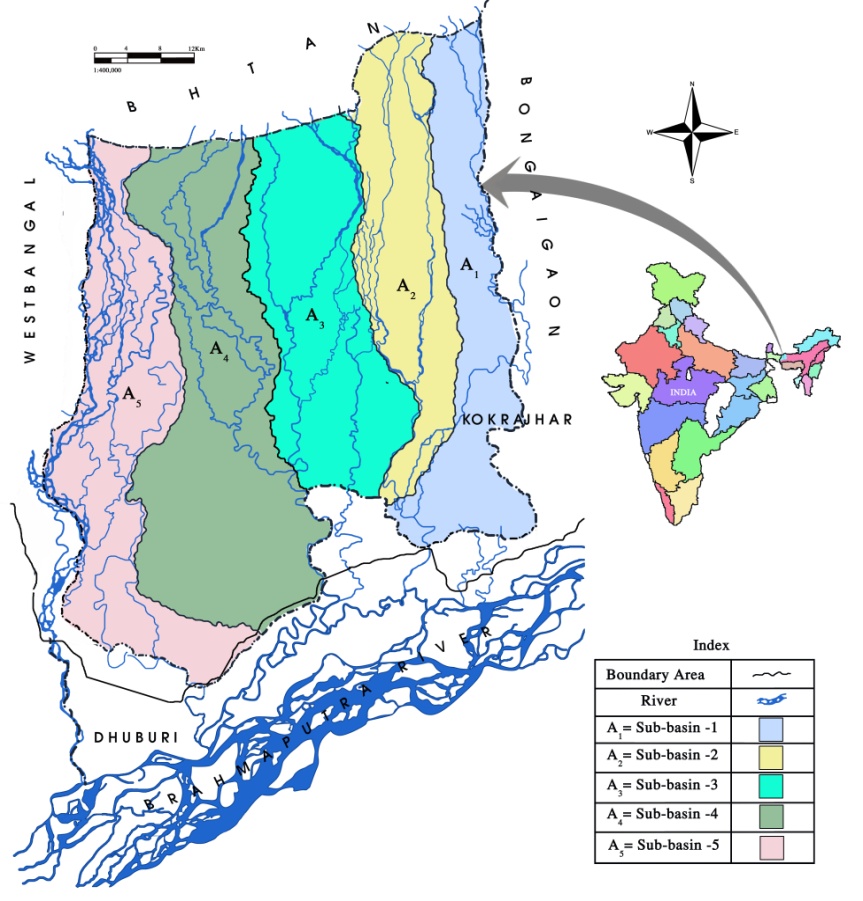


Figure 4.2 Study area map

Economic factor

Environmental factor

Social factor

**Ranking of Alternatives**

Rainstorm (C11)

Embankment Break (C12)

Drainage Density (C13)

Basin Area (C14)

Wetland (C15)

Population growth (C21)

Population Density (C22)

Housing Density (C23)

Industrial growth (C24)

Gross Domestic Product (C31)

Urban Area Ratio (C32)

Annual flood Damage (C33)

Annual flood Coverage (C34)

Figure 4.3 Hierarchical structure of the problem

Several interviews were arranged with the experts to acquire the judgments on the five alternatives on the weights of the 13 criteria. The objective of the first meeting is to introduce proposed framework and to provide the objective data obtained already. The expersts were approached to give their conclusions on the rating of alternatives by utilizing the etymological factors concerning every standard and the significance loads of the criteria.

**4.4.2 The steps of rating of flood vulnerability region can be defined as follows:**

**Step-1**: Six decision makers (Experts) use the linguistic weighting variable shown in fig. 4.4 to evaluate the ratings of alternatives with respect to each criterion as shown in Table 4.3. Also the decision maker uses the linguistic variable shown in Fig. 4.5 to assess the important of the criteria. The important weights of the criteria determined by these six decision makers are shown in table 4.4.

**Step-2:** The OWA weights are determined using the normal distribution based-method suggested by (Xu, 2005) and Eqn –(4.1) to Eqn-(4.3), As a result, the OWA weight vector for six decision makers is computed as

ω = (0.0865, 0.1716, 0.2419, 0.2419, 0.1717, 0.0865)T

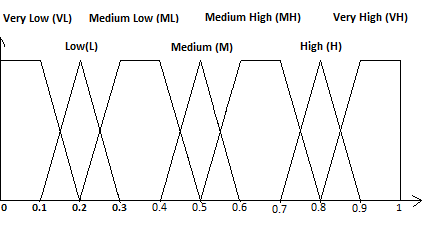


Figure4.5. Linguistic variables for rating the criteria (Yucenur , 2012)

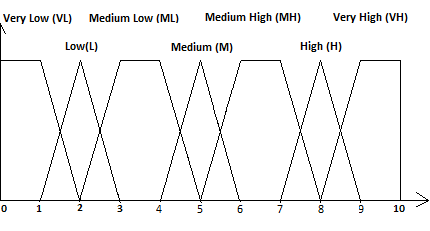


Figure4.4. Linguistic variables for rating of alternatives (Yucenur 2012)

**Step-3**: The evaluation shown in Table 4.3 and 4.4 are converted into trapezoidal fuzzy numbers and the aggregated fuzzy rating of alternatives of each criterion, by using table 4.1 and table 4.2 are shown in table 4.5

**Table 4.**1:

Linguistic variable scales for rating of alternatives (Shemshadi, 2011)

|  |
| --- |
| Linguistic variable Fuzzy Number |
| Very High(VH) (8,9,10,10)  High(H) (7, 8, 8, 9)  Medium High(MH) (5, 6, 7, 8)  Medium(M) (4, 5, 5, 6)  Medium Low(ML) (2, 3, 4, 5)  Low(L) (1, 2, 2, 3)  Very Low(VL) (0, 0, 1, 2) |

**Table** 4.2:

Linguistic variable scales for rating the criteria weights (Shemshadi, 2011)

|  |
| --- |
| Linguistic variable Fuzzy Number |
| Very High(VH) (0.8,0.9,1.0,1.0)  High(H) (0.7,0.8,0.8,.09)  Medium High(MH) (0.5,0.6,0.7,0.8)  Medium(M) (0.4,0.5,0.5,0.6)  Medium Low(ML) (0.2,0.3,0.4,0.5)  Low(L) (0.1,0.2,0.2,0.3)  Very Low(VL) (0.0,0.0,0.1,0.2) |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 4.3 | | | | | | | | | | | | | | | |
| Linguistic assessment of alternatives given by six experts | | | | | | | | | | | | | | | |
| Experts | Alternatives | | Criteria | | | | | | | | | | | | |
|  |  | C11 | | C12 | C13 | C14 | C15 | C21 | C22 | C23 | C24 | C31 | C32 | C33 | C34 |
| **E1** | A1 | MH | | H | VL | L | M | L | M | L | L | M | L | L | ML |
|  | A2 | M | | M | L | ML | L | M | ML | M | L | ML | M | ML | ML |
|  | A3 | ML | | L | M | ML | M | ML | M | L | L | L | M | ML | M |
|  | A4 | MH | | ML | M | ML | MH | M | ML | L | ML | ML | L | M | ML |
|  | A5 | ML | | MH | L | M | M | ML | ML | L | L | ML | L | VL | M |
|  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |
| **E2** | A1 | MH | | H | L | L | ML | L | M | L | L | M | L | L | M |
|  | A2 | M | | M | L | ML | L | M | ML | M | L | ML | M | ML | ML |
|  | A3 | M | | L | M | L | ML | M | ML | M | L | L | M | ML | L |
|  | A4 | MH | | M | ML | M | L | M | ML | ML | VL | M | L | M | ML |
|  | A5 | ML | | MH | L | M | M | ML | ML | L | L | ML | L | ML | VH |
| **E3** | A1 | H | | MH | L | M | H | M | M | M | L | MH | L | ML | ML |
|  | A2 | H | | H | M | ML | MH | H | H | H | M | L | M | ML | ML |
|  | A3 | H | | MH | ML | MH | VH | M | M | MH | VL | M | ML | ML | ML |
|  | A4 | MH | | M | ML | MH | ML | MH | M | M | L | MH | L | M | MH |
|  | A5 | H | | MH | ML | H | VH | M | M | MH | L | VH | ML | VH | H |
| **E4** | A1 | VH | | H | M | MH | L | MH | MH | MH | VL | MH | L | ML | M |
|  | A2 | VH | | H | ML | M | L | MH | M | ML | VL | MH | L | MH | H |
|  | A3 | VH | | M | ML | MH | L | MH | M | MH | ML | M | VL | MH | ML |
|  | A4 | MH | | H | ML | M | ML | M | M | L | VL | MH | M | MH | H |
|  | A5 | VH | | MH | ML | M | L | MH | M | MH | L | H | VL | MH | M |
|  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |
| **E5** | A1 | H | | MH | M | MH | L | MH | ML | MH | VL | MH | L | M | MH |
|  | A2 | VH | | H | M | MH | ML | H | MH | MH | VL | H | MH | H | MH |
|  | A3 | MH | | M | ML | M | L | MH | M | M | VL | MH | VL | MH | H |
|  | A4 | H | | MH | M | ML | MH | H | MH | MH | L | H | L | MH | H |
|  | A5 | VH | | H | VL | M | MH | H | MH | H | L | MH | VL | ML | MH |
| **E6** | A1 | H | | M | M | ML | M | MH | MH | MH | L | MH | M | MH | H |
|  | A2 | H | | VH | M | ML | L | H | MH | H | VL | H | M | H | MH |
|  | A3 | MH | | H | VL | M | ML | MH | M | M | VL | MH | VL | MH | M |
|  | A4 | H | | MH | M | MH | L | MH | M | MH | L | MH | M | MH | H |
|  | A5 | H | | VH | MH | ML | M | H | MH | H | L | H | MH | ML | MH |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 4.4 | | | | | | | | | | | | | | |
| Linguistic assessment of criterion weights | | | | | | | | | | | | | | |
| **Experts** | **Criteria** | | | | | | | | | | | | |
|  | C11 | C12 | C13 | C14 | C15 | C21 | C22 | C23 | C24 | C31 | C32 | C33 | C34 |
| **E1** | H | MH | M | M | H | MH | M | ML | ML | MH | M | H | MH |
| **E2** | VH | MH | M | M | H | MH | M | ML | ML | ML | M | H | ML |
| **E3** | H | VH | L | M | H | MH | MH | H | H | ML | L | M | M |
| **E4** | VH | H | M | MH | ML | H | MH | M | MH | H | M | H | MH |
| **E5** | H | VH | M | M | VL | H | MH | M | L | H | ML | H | MH |

Table 4.5

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

Criteria Alternatives

A1 A2 A3 A4 A5 Weights

C11 (6.570,7.570,7.915,8.828) (6.484,7.484,7.742,8.484) (5.172,6.172,6.828,7.742) (5.516,6.516,7.258,8.258) (5.796,6.796,7.141,8.054) (**0.726,0.826,0.852,0.926**)

C12 (5.914,6.914,7.327,8.327) (6.312,7.312,7.399,8.312) (3.657,4.657,4.828,5.828) (4.500,5.500,6.000,7.000) (6.087,7.087,7.673,8.587) (**0.698,0.798,0.874,0.924**)

C13 (2.414,3.327,3.414,4.414) (2.742,3.742,3.984,4.984) (2.000,2.742,3.484,4.484) (3.000,4.000,4.500,5.500) (2.001,3.001,3.743,4.743) (**0.383,0.483,0.491,0.591**)

C14 (3.000,4.000,4.500,5.500) (2.603,3.603,4.431,5.431) (3.655,4.655,5.085,6.085) (3.742,4.742,5.258,6.258) (4.087,5.087,5.173,6.173) (**0.426,0.526,0.552,0.652**)

C15 (3.001,4.001,4.243,5.243) (1.518,2.518,2.776,3.776) (2.604,3.604,4.174,5.088) (2.516,3.516,4.258,5.258) (4.760,5.760,6.260,7.173) (**0.433,0.524,0.574,0.674**)

C21 (3.726,4.726,5.226,6.226) (5.742,6.742,6.984,7.984) (4.327,5.327,5.914,6.914) (4.673,5.673,6.087,7.087) (4.726,5.726,5.726,6.726) (**0.552,0.652,0.726,0.826)**

C22 (4.601,5.601,5.688,6.688) (4.157,5.157,5.828,6.828) (3.827,4.827,4.914,5.914) (3.570,4.570,4.915,5.915) (3.984,4.984,5.742,6.742) (**0.450,0.550,0.650,0.750**)

C23 (3.726,4.726,5.226,6.226) 4.843,5.843,6.172,7.172) (3.999,4.999,5.257,6.257) (3.000,4.000,4.500,5.500) (4.968,5.968,6.210,7.210) (**0.374,0.474,0.500,0.600**)

C24 (0.742,1.484,1.742,2.742) 0.760,1.260,1.760,2.760) (0.587,1.087,1.673,2.673) (0.828,1.570,1.915,2.915) (1.000,2.000,2.000,3.000) (**0.269,0.369,0.434,0.534**)

C31 (4.742,5.742,6.484,7.484) 3.930,4.930,5.585,6.585) (3.484,4.484,4.742,5.742) (4.742,5.742,6.484,7.484) (4.485,5.485,6.485,7.399) (**0.393,0.493,0.559,0.659**)

C32 (1.260,2.260,2.260,3.260) 3.827,4.827,4.914,5.914) (0.587,1.087,1.673,2.673) (1.774,2.774,2.774,3.774) (0.345,0.603,1.431,2.431) (**0.340,0.440,*0*.440,0.540**)

C33 (2.345,3.345,3.915,4.915) 4.016,5.016,5.758,6.758) (3.500,4.500,5.500,6.500) (4.500,5.500,6.000,7.000) (3.204,4.118,4.946,5.859) (**0.674,0.774,0.774,0.874**)

C34 (3.915,4.915,5.345,6.345) 3.673,4.673,5.586,6.586) (2.087,3.087,3.914,4.914) (5.226,6.226,6.726,7.726) (5.430,6.430,7.085,8.085) (**0.483,0.583,0.657,0.748**)

**Step-4:** The best and the worst values of all criterion rating are determined by using eq. –(4.7) and (4.8) and shown in table 4.6.

Table 4.6

The fuzzy best and fuzzy worst values of all criteria ratings

|  |  |  |  |
| --- | --- | --- | --- |
| G\*1 | (6.570,7.570,7.915,8.828) | 1 | (5.172,6.172,6.828,7.742) |
| G\*2 | (6.312,7.312,7.399,8.312) | 2 | (3.657,4.657,4.828,5.828) |
| G\*3 | (3.000,4.000,4.500,5.500) | 3 | (2.001,3.001,3.743,4.743) |
| G\*4 | (4.087,5.087,5.173,6.173) | 4 | (2.603,3.603,4.431,5.431) |
| G\*5 | (4.760,5.760,6.260,7.173) | 5 | (1.518,2.518,2.776,3.776) |
| G\*6 | (5.742,6.742,6.984,7.984) | 6 | (3.726,4.726,5.226,6.226) |
| G\*7 | (4.157,5.157,5.828,6.828) | 7 | (3.570,4.570,4.915,5.915) |
| G\*8 | (4.968,5.968,6.210,7.210) | 8 | (3.000,4.000,4.500,5.500) |
| G\*9 | (1.000,2.000,2.000,3.000) | 9 | (0.587,1.087,1.673,2.673) |
| G\*10 | (4.742,5.742,6.484,7.484) | 10 | (3.484,4.484,4.742,5.742) |
| G\*11 | (3.827,4.827,4.914,5.914) | 11 | (0.345,0.603,1.431,2.431) |
| G\*12 | (3.204,4.118,4.946,5.859) | 12 | (2.345,3.345,3.915,4.915) |
| G\*13 | (5.226,6.226,6.726,7.726) | 13 | (2.087,3.087,3.914,4.914) |

**Step-5**: The normalized fuzzy distance calculated by Eqn –(4.9) for each criterion of the alternative are shown in table 4.7

**Step-6**: Defuzzify the fuzzy criteria weights to get crisp values by using Eqn –(4.10) and result shown in along in last column of table 4.7

Table 4.7

Normalized fuzzy distance for the five alternatives.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Criteria | Alternatives | | | | | | |
| A1 | A2 | A3 | A4 | A5 | **Weights** | |
| C11 | 0.000 | 0.134 | 0.831 | 0.572 | 0.514 | | **0.831** |
| C12 | 0.090 | 0.000 | 0.822 | 0.507 | 0.080 | | **0.822** |
| C13 | 0.488 | 0.259 | 0.593 | 0.000 | 0.487 | | **0.487** |
| C14 | 0.415 | 0.539 | 0.143 | 0.115 | 0.000 | | **0.539** |
| C15 | 0.308 | 0.552 | 0.350 | 0.348 | 0.000 | | **0.552** |
| C21 | 0.689 | 0.000 | 0.457 | 0.359 | 0.416 | | **0.689** |
| C22 | 0.258 | 0.000 | 0.538 | 0.600 | 0.107 | | **0.600** |
| C23 | 0.296 | 0.024 | 0.254 | 0.487 | 0.000 | | **0.487** |
| C24 | 0.248 | 0.309 | 0.402 | 0.174 | 0.000 | | **0.402** |
| C31 | 0.000 | 0.296 | 0.526 | 0.000 | 0.065 | | **0.526** |
| C32 | 0.312 | 0.000 | 0.403 | 0.250 | 0.440 | | **0.440** |
| C33 | 0.774 | 0.731 | 0.416 | 1.045 | 0.000 | | **0.774** |
| C34 | 0.279 | 0.282 | 0.617 | 0.000 | 0.061 | | **0.617** |

**Step-7 and 8**: The calculated the values of Si, Ri and Qi, i= 1,2, ... , m are shown in table 4.8.

Table 4.8

The value of S, R, and Q for all alternatives

Alternatives

A1 A2 A3 A4 A5

S 0.536 0.403 0.818 0.574 0.279

R 0.100 0.094 0.107 0.135 0.066

Q 0.483 0.319 0.798 0.774 0.000

**Step-9:** The ranking of all alternatives by S, R and Q in increasing order are shown in table 4.9

Table 4.9

The ranking of alternatives ordered by S, R, and Q in increasing order

Alternatives

A1 A2 A3 A4 A5

By S 3 2 5 4 1

By R 3 2 4 5 1

By Q 3 2 5 4 1

**Step-10:** In this context of flood vulnerability, it suggests that the river basin region needs to implement adaption plan with the highest priority based on the vulnerability scores and ranking.

As we see in table 4.9 the alternatives (A5) based on Q is apparently the best (most vulnerability) compromise solution, two conditions C1 and C2 are also satisfied:

Q (A2) (2)- Q(A5)(1)=(0.319-0)=0.319 ≥

And **A5** is the best ranked (best compromise solution) by R and S Graph of S, R and Q are shown in Figure 4.6

Table 4.10

Criteria wise ranking of five alternatives.

Criteria Ordering of Alternatives (decreasing)

High to low

C11 A1 A2 A5 A4 A3

C12 A2 A5 A1 A4 A3

C13 A4 A2 A5 A1 A3

C14 A5 A4 A3 A1 A2

C15 A5 A1 A4 A3 A2

C21 A2 A4 A5 A3 A1

C22 A2 A5 A1 A3 A4

C23 A5 A2 A3 A1 A3

C24 A5 A4 A1 A2 A3

C31 A2 A1 A5 A2 A3

C32 A2 A4 A1 A3 A5

C33 A5 A4 A3 A2 A1

C34 A4 A5 A1 A2 A3

Table 4.11

Ranking of criteria weights. Ordering (High to low)

1 2 3 4 5 **6** 7

C11 C12 C33 C21 C34 C22 C15

Ordering

8 9 10 11 12 13

C14 C31 C13 C23 C32 C24

Figure 4.6 Ranking of Alternatives by S R and Q

* 1. **RESULT AND DISCUSION:**

Table 4.10 shows criteria wise ranking of the vulnerability of five alternatives (sub basin) discus in this study. The result shows that the alternative A1 -Sub basin1 (Champamati River basin) is the highest vulnerability in the criteria C11, alternative A2 -Sub basin2 (Gourang-Sharalbhanga River basin) is the highest vulnerability in the criteria C12, C21, C22, C31, C32, alternative A4 -Sub basin4 (Modati-Joyma-Tipkai River Basin) is the highest vulnerability in the criteria C13, C34, alternative A5 -Sub basin5 (Songkosh-Gadadhar River basin) is the highest vulnerability in the criteria C14, C15, C23, C24, C33 respectively and alternatives A1 basin1 (Champamati River basin) is the lowest vulnerability in the criteria C21 and C33, alternatives A2 basin2 (Gourang-Sharalbhanga River basin) is the lowest vulnerability in the criteria C14 and C15, and alternative A3 -Sub basin3 Sub basin3 (Hel- Gongia River basin) is the lowest vulnerability in the criteria C11, C12, C13, C23, C24, C31, C32, C34

Table 4.11 shows ranking criteria weights, criteria C11 (Rainstorm) is the highest weights as per the experts followed by C12 (Embankment Break) and C33 (Annual flood Damage) respectively while criteria C24 (Industrial growth) has the least criteria weights. Ranking of Criterion weights are shown in Figure 4.7

Figure 4.7 Ranking of Criterion weights

* 1. **CONCLUSION:**

In this study, we assessed the flood vulnerability in Kokrajhar region with Fuzzy VIKOR. We defined the flood helplessness as an element of Environmental factor, social factor and financial elements, and we profiled the key indicators for weakness with the master's opinions. Fuzzy VIKOR technique is a useful instrument in multi criteria decision making bargained arrangement which obtained, could be acknowledged by the decision creators since it gives a most extreme gathering utility (spoke to by min S) of the larger part, and a minimum of the individual lament (spoke to by min R) of the adversary. In this chapter we proposed a modified Fuzzy VIKOR that was supported by OWA operator and determined the weights of criteria. According to the final score, the alternative A5 (minimum of Q) that the Songkosh-Gadadhar river sub-basin is the most vulnerable region while A2 and A1 alternatives are second and third most vulnerability river basin region.

**Chapter- 5**

STRUCTURAL FLOOD CONTROL MODELLING

**AHP and Fuzzy VIKOR Approach modelling for flood control project selection**

**5.1 INTRODUCTION**

**5.2 FLOOD CONTROL PROJECT LTERNATIVES**

**5.3 APPLICATIONS OF PROPOSED FRAMWORK**

**5.4 CONCLUSION**

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**5.1** **INTRODUCTION:**

In this section we proposed flood control venture that information are estimated dependent on information gathered through polls from the specialists in triangular fuzzy number structure. In this proposed approach, the chiefs' conclusions on the weighting of criteria are dictated by a fuzzy AHP method. The positioning an incentive at the conglomerating part is dictated by Fuzzy VIKOR strategy.

Surveying various examinations on flood control activity the MCDM technique in the determination procedure have the incredible appropriateness. As indicated by Akter T. et al. (2002) flood management basic leadership issue frequently include different targets and numerous partners. To empower increasingly powerful and adequate choice results uncertainty assumes a significant job in flood management basic leadership process. In (1975) Zadeh and Buckley (1985) have presented a fuzzy set idea that are progressively solid to deal with all the uncertainty. The greater part of the prior paper Chen et al. (2004); Carlos et al. (2004) and Ahmed et al. (2000) of flood control venture utilized just the subjective and quantitative information in fuzzy number structure.

The remainder of the part is sorted out as pursues: in area 5.2, we learn about the flood control choices and choice of criteria in flood management control venture. In area 5.3 We applied the proposed structure for the instance of Aie stream bowl of Chirang District, BTAD, Assam, India, lastly end have been attracted segment 5.4.

* 1. **FLOOD CONTROL PROJECT ALTERNATIVES:**

The main goal of flood control planning is to lessen the flood harm in a minimum consistent with the cost involved. The flood control options can be arranged into two gatherings: basic and non basic. Basic choices speak to customary flood harm decrease by physical methods (Zamri et al. 2013)

* 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/repositories might be built over the upper stream of the waterway to store rising water s and the extent of the rising water can be diminished the downstream phase of the flood. The store water can be utilized to produce the power and agrarian purposes. | |
|  |  | |
| **A2 – Embankment and side Bands** | It is the most seasoned generally utilized techniques for assurance against the floods. Dikes are built parallel to the waterways to avoid floods of rising water to the flood plain. | |
| **A3 –De-silting and dredging** | De-silting and dredging of waterway is likewise valuable technique that improves the pressure driven limit of channel can bring down the water stage and increase the carrying limit of water. | |
| **A4 – Channel diversion** | A counterfeit channel can be utilized to redirect the rising water that can increase the flood release and can diminish the harm. | |

1. **Identification of decision making criterion:**

The venture determination process is generally troublesome and it involves enormous investment for execution. The effect on condition and social likewise high and might be as high as the expense of execution of task (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) |

* 1. **APPLICATIONSOF PROPOSED FRAMWORK**

**5.3.1 Case study**

Aie Manas River which is begins operating at a profit Mountains of Bhutan at the height around 4,915 meters close to the town of Bangpari, is about 110km long goes through Chirang District, BTAD (Bodoland Territorial Area District), (in Fig.3) Assam. These stream falls under the Manas-Beki-Aie sub bowl. It is one of the greatest and significant sub bowl of Brahmaputra stream bowls. The sub bowl lies between elevation 26ͦ 15N and 28ͦ 40N and longitude 90ͦ 13'E and 92ͦ 18'E. The whole course of Aie has been encountering the common procedure of self change of its area of parameters. The greatest normal downpour fall is about 2448.8mm every year [48]. The most noteworthy temperature recorded in the region is 35.30ͦ c and least is 8.20ͦ c. Throughout the previous ten years around 1270 quantities of houses has been harmed because of the disintegration and a few pieces of town has been dislodged (2013-14) according to 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

* + 1. **Priority weight for decision criteria by (FAHP)**

As per proposed model, the principle target of utilizing Fuzzy AHP is to decide significant load of the criteria that will be utilized in Fuzzy VIKOR strategy (Chang, 2011). As indicated by the proposed model the loads of the Criteria and sub criteria can be broke down (appeared in Table 5.2). A board of three specialists (Decision Makers) was chosen to discover the loads 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 method for deciding the loads is as per the following.

Step-1: The specialists were approached to give the rate pair shrewd correlations with every paradigm recognized in table 5.2 as indicated by the linguistic variable according to table 5.3 and the rating acquired are exhibited in the table 5.4.

Step-2: The linguistic variable are changed over to the relating Triangular Fuzzy Numbers (TFNs) and totaling the components of manufactured pairwise examination grid by utilizing Geometric mean technique proposed by (Lee 2009) ( Eq-(5.1) that is: appeared in table 5.5, ,

(5.1)

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

**Step 3**: Similarly, Fuzzy geometric mean of pairwise examination grid of sub rule are registered and afterward Important loads that is need vector fresh relative for distinguished criteria is acquired from the count dependent on pairwise correlation frameworks by utilizing eq. (2.2) to eq. (2.7), the degree examination strategy proposed by Chang (1996) and values are introduced in the table 5.6. We are utilizing this basis weight for positioning the options in fuzzy VIKOR strategy

|  |  |  |  |
| --- | --- | --- | --- |
| 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) |

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| 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 | Sub | Weight | Final weights |
|  | (*w*i) | Criteria | (wij) | (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 |

* + 1. **Application of Fuzzy VIKOR for ranking Alternatives**

This progression fuzzy VIKOR technique is applied for the determination of best auxiliary flood control venture as the options appeared in the (table 5.1). The assessments fundamental criteria and sub-criteria appeared in Table 5.2. There are four principle criteria and twelve sub standards are considered in this examination.

Above all else a board of trustees of three specialists has been recognized they are E1-Project Director (District Disaster Management), E2-Executive Engineer Irrigation Department E3-Assistant Project Director (District Disaster Management)

We used the fuzzy-VIKOR strategy to decide the best flood control venture choices comprises of the accompanying advances.

**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) | |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 5. 8 | | | | | | | | | | | | | |
| Linguistic assessment of alternatives given by three experts | | | | | | | | | | | | | |
| Experts openion | Alternatives | Criteria | | | | | | | | | | | |
| Ec1 | Ec2 | Ec3 | Sc1 | Sc2 | Sc3 | Ev1 | Ev2 | Ev3 | Tc1 | Tc2 | Tc3 |
| E1 | A1 | B | F | F | G | G | B | F | F | G | B | P | F |
|  | A2 | B | F | G | F | P | G | F | F | G | G | F | F |
|  | A3 | G | P | G | B | P | P | G | F | G | F | F | P |
|  | A4 | B | G | P | G | F | F | B | F | B | B | F | P |
| E2 | A1 | B | F | F | B | P | B | P | P | G | G | W | P |
|  | A2 | B | P | P | P | B | L | P | P | F | G | F | P |
|  | A3 | B | G | G | F | G | P | F | G | F | P | P | G |
|  | A4 | P | F | P | G | F | P | F | F | F | F | B | P |
| E3 | A1 | B | G | F | F | P | B | G | F | B | P | W | P |
|  | A2 | G | F | P | G | F | F | F | G | G | F | W | P |
|  | A3 | B | P | G | F | F | P | F | P | G | F | F | B |
|  | A4 | G | F | B | F | P | G | B | P | G | F | F | 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 Si, Ri and Qi, 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 |

# CONCLUSION

The fuzzy VIKOR strategy centers around positioning and choosing from a lot of choices in a fuzzy domain. Because of its attributes and abilities, the fuzzy VIKOR technique has been broadly contemplated and applied in flood hazard management issues. The fuzzy VIKOR technique depends on collecting fuzzy measure Q that speaks to the separation of an option in contrast to the perfect arrangement. In this exploration, we join fuzzy VIKOR and fuzzy AHP way to deal with build up a progressively exact flood control venture determination procedure. A numerical model represents a use of fuzzy VIKOR technique. It is an aim to show the calculated and operational defense of the utilization of the technique in certifiable issue.

**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.**

* 1. **INTRODUCTION**

**6.2 FUZZY PROMETHEE**

**6.3 APPLICATION OF THE MODEL TO CASE ILLUSTRATION**

**6.4 COMPARISION AMONG MCDM METHOD**

**6.5 SENSITIVITY ANALYSIS**

**6.6 CONCLUSION**

**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 determination, that data are evaluated subject to data accumulated by polls from the specialists in triangular fuzzy number structure. In this proposed framework, the leader's feeling on the weighting of criteria is determined by a fuzzy AHP philosophy. The positioning of option is controlled by Fuzzy PROMETHEE strategy.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 and the results of the chapter are considered in the last section, Section 6.5.

**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 objective programming for gear choice, material taking care of hardware choice issues. Tuzkaya et al. (2010), framework data re-appropriating Chen et al. (2011), the perfect eco-advancement judgments for a practical structure site Chou et al. (2007) , Geldermann and Rentz (2001) contributed fuzzy PROMETHEE for environmental assessment and developed a graphical affectability examination. Wang et al. (2008), contributed for picking redistributed suppliers. Bilsel et al. (2006) showed fuzzy PROMETHEE for positioning medicinal facility destinations. Geldermann et al. (2000) contributed fuzzy PROMETHEE with trapezoidal fuzzy interim numbers and show an application for the natural appraisal of iron and steel adventures. 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’ , 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 is calculated to signify the preferences of all other alternatives measured against *n*. This is likewise indicated as the 'incoming flow', 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 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)

RI

EI LI FI VI AI

1/2

1

3

7/2

2

5/2

3/2

µ RI

1.0

|  |  |  |  |
| --- | --- | --- | --- |
| 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 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 denotes the weights of the jth criterion based on the linguistic term preference assigned by a decision maker.

It is noted that each weight is expressed as a TFN.

, j= 1, 2, …, n (6.2)

Figure6. 2 Linguistic scales for evaluation

EI LI FI VI AI

RI

µ RI

1.0

2.5

7.5

10

5

0

|  |  |  |  |
| --- | --- | --- | --- |
| **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

, where k=1,2, …K , the the aggregated fuzzy rating can be determined as , k=1, 2, .. K

, , (6.3)

**Step 5**: Construction of the fuzzy decision matrix

The fuzzy decision matrix for the alternatives is constructed as follows:

, where i=1, 2, …,m : j=1, 2, … n (6.4)

Where is the rating of alternatives Ai under the criterion Cj both expressed in TFNs. The TFNs of K decision maker k is

**Step 6**: Normalized the Fuzzy decision matrix.

The aggregated fuzzy decision matrix from 5 step is standardized utilizing straight scale change to bring the different criteria scales into equivalent scale. The standardized Fuzzy choice network R ̃ can be gotten as

(6.5)

Where and

**Step-7**: Construct weighted standardized Fuzzy decision matrix

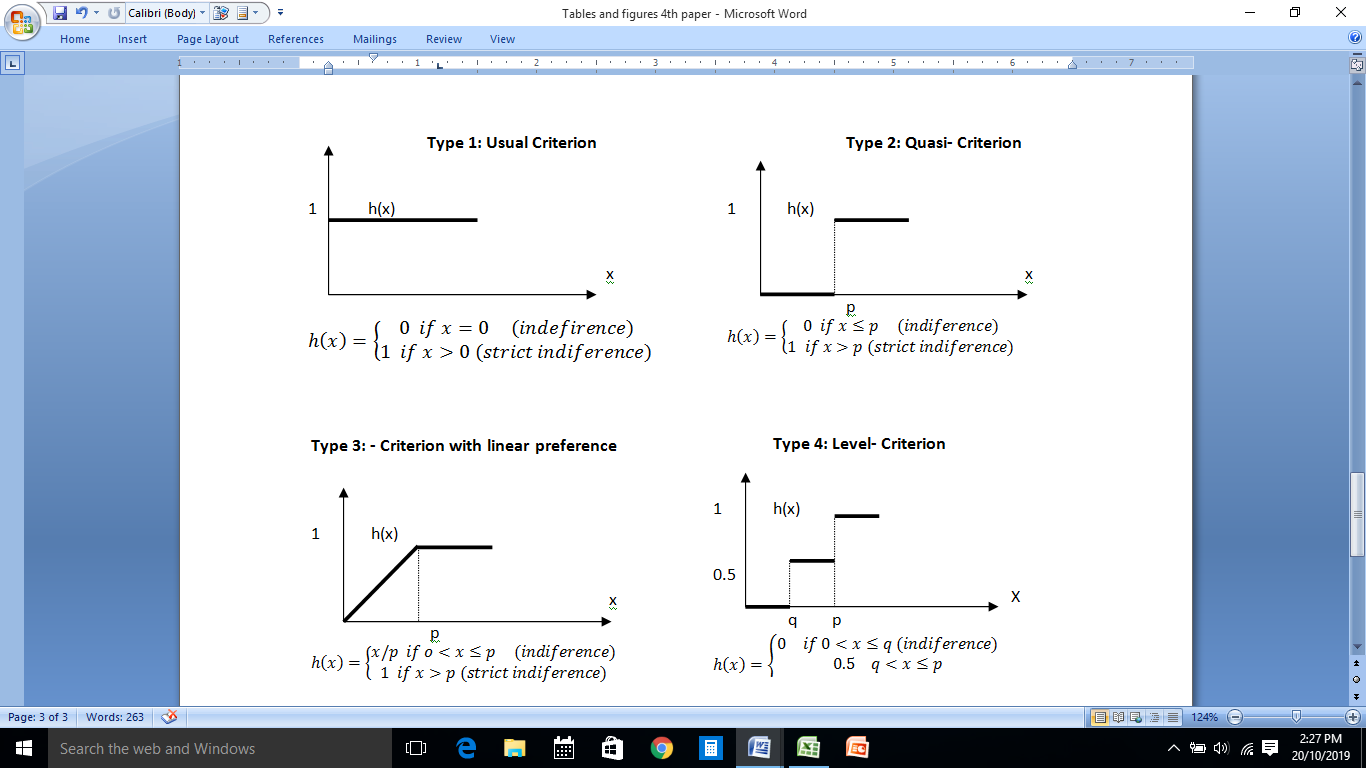
Thinking about the diverse load of every model, the weighted standardized choice network is assessed by duplicating the significance loads of assessment criteria and the qualities in the standardized fuzzy choice framework. The weighted standardized choice framework V is defined as

(6.6)

, where W is the criterion weighted calculated by using Fuzzy AHP

**Step 8**: De fuzzy The normalized triangular fuzzy number, is defuzzified by the following method

(6.7)



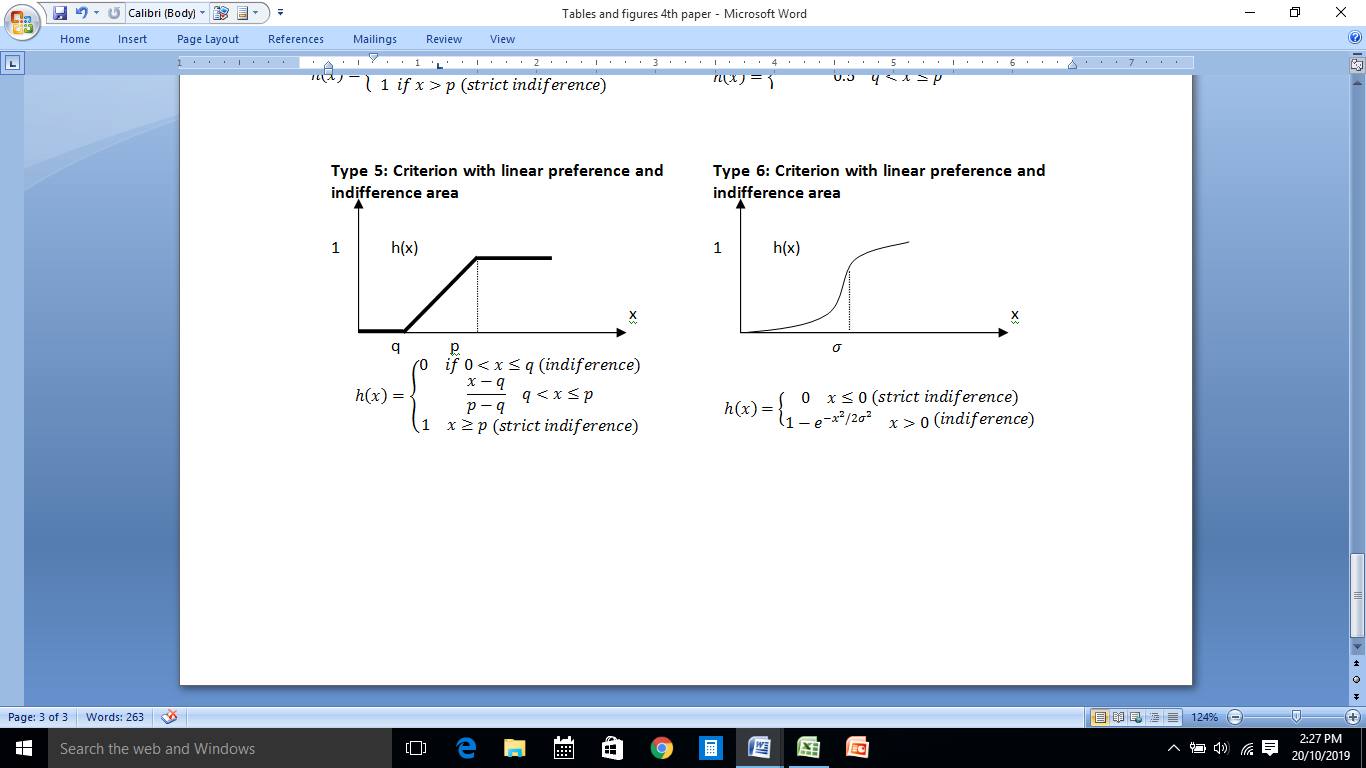


Figure 6.3 General preference functions of PROMETHEE

**Step 9**: Construction of the fuzzy preference function

The fuzzy preference function 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={a1, a2, …, an} and F= {g1, g2, …,gn} a finite set of criterion on which the ranking of alternatives to be evaluated. With each of criterion gj, j=1,2,…, m, is assigned a weight wj 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

j=1, 2 , …,k (6.8)

**Step 10**: Computation of weighted aggregated preference function

Out ranking degree, for each pair of alternatives is computed in the following way:

(6.9)

and are number between 0 and 1 that are a function of

**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 and incoming flow are calculated by equation (24) and (25), n refers to the number of alternatives.

Where indicates the sum of preference that **a** is greater to other alternatives. The greater the the better the alternatives **a**.

Where indicates the sum of preference that other alternatives is greater to a. The smaller the 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 Eqn-(6.12) is satisfied (Tuzkzya et al. 2010; M. Gul et al. 2018)

(*aPb*), if : and OR

and OR (6.12)

and 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* if : and (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* if : and OR

And OR (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**.

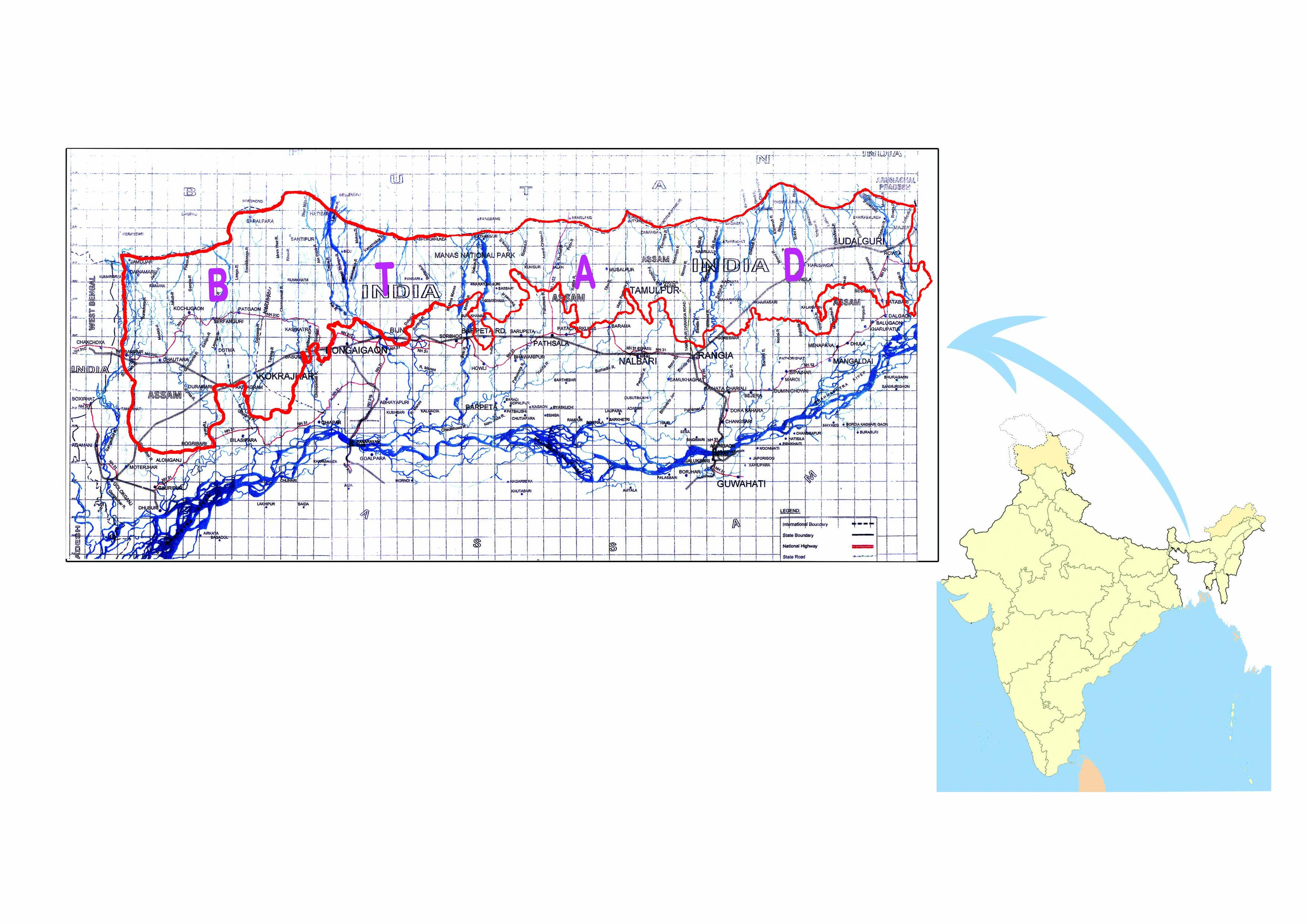
(6.15)

**6.3 APPLICATION OF THE MODEL TO CASE ILLUSTRATION**

**6.3.1 Study Area**

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

**6.3.2 Flood Control Alternatives**

Figure 6.4 River systems under the BTAD

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.

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.

*Economic factors (C1)*

* Cost of project
* Operation and maintenance
* Project benefit
* Reliability economic parameter

*Technical factors (C2)*

* Complexity of implementation
* Level of protection
* Project Flexibility
* Complexity of maintenance

*Environment factors (C3)*

* Ecological Restoration
* Land Erosion
* Water Quality
* Land use

*Social factors (C4)*

* Social acceptability
* Demographic changes
* Effects on infrastructure
* Recreation activity

**Final Target (FT)**

Determination of most suitable flood control alternatives

Figure 6.5. De*c*ision Main criteria and sub criteria.

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.

**Best flood control Project**

Economic Factor (C1)

Technical factor (C2)

Environmental factor (C3)

Social factor (C4)

Dam / reservoirs (A1)

Levees / Embankment and side walls (A2)

Channel diversion (A3)

Channel dredging Improvement (A4)

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 various offices one (SDCO), another from (DDMA), two are official Engineers under the water asset office one from water system office. 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 Eqn-(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 Eqn-(2.2) to Eqn-(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 Eqn –(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

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)

A1 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)

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)

A2 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)

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)

A3 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)

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)

A4 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 Eqn-(6.5) and (6.7) respectively (shown in Table 6.9) and then de fuzzyfied by Eqn-(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 Eqn-(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 Eqn- (6.9), then the outgoing flow incoming flow and net flow are calculated by using Eqn (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 Eqn.-(6.12) via the fuzzy PROMETHEE I method. Basically, the greater the outgoing flow ( value) and the smaller the incoming flow( 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 ( value) is calculated by the fuzzy PROMETHEE II method by using Eqn- (6.15) The greater the net flow ( 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)

**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 Eqn- (6.16)

FPIS and FNIS (6.16)

Where and ; 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 dv of each Alternatives from FPIN (F\*) and FNIS (F-) are computed by using Eqn.(6.17) and (6.18). As follows:

(6.17)

(6.18)

Where is the distance measurement between two Fuzzy numbers.

The distance and of Ai (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 |

The closeness coefficient (CCi) of each alternative is calculated by the equation (6.19)

(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 (CCi) of alternatives and their final ranking | | | | | | | | | | | | |
|  | **Alternatives** |  | |  | | **+** | | |  | | **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,) and fuzzy worst value (FWV, ) 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.

(6.20)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Table 6.16 | | | | | | | |
| Fuzzy Best Value and Fuzzy Worst Value | | | | | | | |
|  | 3.913 | 6.580 | 8.660 |  | 2.973 | 5.533 | 8.059 | |
|  | 4.653 | 7.282 | 9.306 |  | 0.000 | 5.149 | 7.825 | |
|  | 1.000 | 5.533 | 7.825 |  | 0.000 | 4.653 | 7.330 | |
|  | 1.000 | 7.282 | 9.306 |  | 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 dij, i=1,2,m, j=1,2,...n

(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 Si, Ri and Qi, i = 1, 2, . . . , m are calculated by Eqs. (6.22)– (6.23) And the results are shown in table 6.18

(6.22)

(6.23)

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

(6.24)

Where , , , what's more, v is presented as a load for the methodology of most extreme gathering utility, though (1 – v) is the heaviness of the individual lament. The estimation of v is set to 0.5 in this examination 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 | | | | | | | | | | | | | | | | | | | | | |
| Alternatives | | Fuzzy PROMETHEE | | | | |  | | Fuzzy TOPSIS | | |  | | | Fuzzy VIKOR (v=0.5) | | | |
| 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 (CCi) 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 2nd most important criteria respectively as it has highest and 2nd 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 key inclinations of the procedure are thought of the dubiousness, vulnerability, and fuzziness to basic leadership condition. The technique proposed here is shown to be an attainable and proficient apparatus for flood control elective assurance when the correct inclination work is chosen by the chiefs.

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

**Chapter -7**

**RESEARCH SUMMARY AND CONCLUSION**

**7.1 RESEARCH SUMMARY**

**7.2 CONCLUSION**

**7.3 RECOMMENDATION**

* 1. RESEARCH SUMMARY

Flood is a geo-climatic and semi common risk with generally high stream which immerses the bank and upsets the characteristic assets alongside the anthropogenic properties. It can be assessed by ranking vulnerability which means judgment process to identify, predict, evaluate and justify the ecological, social and related biophysical effects of a flood on environment.

For the best possible comprehension of the current research problem, the author pursued a ton of Indian and Foreign journals, books, articles, research papers; newspapers etc. Present studies have considered stakeholder involvement to flood vulnerability assessments by multi-criteria decision-making (MCDM) techniques that are employed to aggregate various opinions and factors.

The flood in BTAD is a recurrent problem because the area is consist of multiple river basin upstream is from the high altitude Himalayan Bhutan hills and the river area has an ignorable gradients which creates a problem of stagnation of water and continuously erodes its banks thereby causing threat thousands of inhabitants and villages during the flood. The objectives of the present work are to assess the impact of flood vulnerability on the socio- economical and environment and the required management measures.

Kokrajhar region of BTAD is consider as the study area which is one of the most affected region which consists of three administrative sub-divisions, Kokrajhar, Gossaigaon and Parbathjhara, 9 no. of Circles, 11 no. of Blocks and around 941 villages.

The most common hydrologic vulnerability is watershed approach, the study a reach-based areal approach based on river reach is used. As per the geographical information the study area is divided into five sub- basin region as follows:

A1: (Champamati River basin) A2; (Gourang-Sharalbhanga River basin) A3: (Hel- Gongia River basin) A4: (Modati-Joyma-Tipkai River Basin A5: (Songkosh-Gadadhar River basin)

For the purpose of our study we have consider the following factors related to the flood problem such as environment factor, social factor and economic factors. For the simplicity of our study we have divided the main factors (criteria) into sub criteria as follows: five sub-criteria Rainstorm (C11), Embankment Break (C12), Drainage Density (C13), Basin Area (C14), Wetland (C15) under environment factor, four sub-criteria Population growth (C21), Population Density (C22) , Housing Density (C23), Industrial growth (C24) under social factor and four sub-criteria Gross Domestic Product (C31), Urban Area Ratio (C32), Annual flood Damage (C33), Annual flood Coverage (C34) under economical factor are selected.

Fuzzy VIKOR method and OWA is used to identify the flood vulnerability which is ranking of the river basin area (Alternative) using the above mentioned sub criterion.

This criterions are grade in the form of linguistic variable Very High (VH), High (H), Medium High(MH), Medium(M), Medium Low(ML), Low(L), Very Low(VL) and the Trapezoidal fuzzy number as the fuzzy number. The experts opinion are collected from (SDCO), one from (DDMA), two are executive Engineers under the water resource department one from relief and rehabilitation office and Assistant Professors.

The experts’ opinions in the form of linguistic variable, Trapezoidal fuzzy number and its arithmetic operation are used to assess the rating of the weights for the established criteria. The individual opinions of the experts into group assessment are aggregated by using OWA operator and fuzzy VIKOR is used to rank the basin area alternatives.

The result shows that the alternative A1 -Sub basin1 (Champamati River basin) is the highest vulnerability in the criteria C11, alternative A2 -Sub basin2 (Gourang-Sharalbhanga River basin) is the highest vulnerability in the criteria C12, C21, C22, C31, C32, The criteria C11 (Rainstorm) is the highest weights as per the experts followed by C12 (Embankment Break) and C33 (Annual flood Damage) respectively while criteria C24 (Industrial growth) has the least criteria weights.

The final score the alternative A5 (minimum of Q) that the Songkosh-Gadadhar river sub-basin is the most vulnerable region while A2 and A1 alternatives are second and third most vulnerability river basin region.

One of the most important aspects of flood management is flood control and flood damage reduction of river basin area. Flood control required hydrologic and hydraulic analysis of floods. This analysis determines inundated areas, flood elevation, and characteristics of required hydraulic structures for flood control or flood damage reduction.

A structural model of flood control project is considered in the chapter 5. The development of flood control facilities can be alluded as basic alternatives. In this investigation we think about four Alternatives: A1–Dams and Reservoirs (dams/supplies might be developed over the upper stream of the waterway to store flood water), A2 – Embankment and side Bands (It is the most seasoned generally utilized strategies for security against the floods), A3 – De-silting and digging (improves the pressure driven limit of channel can bring down the water stage) and A4 – Channel redirection (A fake channel can be utilized to occupy the flood water). For ranking these alternatives four main criteria Ec: Economic, Sc: Social, Ev: Environmental and Tc: Technical and 12 sub criteria (Ec1: Cost of Project, Ec2: Implementation and maintenance, Ec3: Benefit of Project, Sc1: Effect on social fabric, Sc2: Perception of flood, Sc3: Recreation Ev1: Ecological Restoration,Ev2: Land Erosion ,Ev3: Water Quality, Tc1: Complexity of implementation, Tc2: Level of protection, Tc3: Complexity of maintenances) are included in the system. Fuzzy AHP Extent Analysis Method Chang (1996) method based on TFN is adopted to determine the weights of the criteria. We then used these weights to rank the best alternative by Fuzzy VIKOR method. A3 –**De-silting and dredging** is the most suitable structural flood control model followed by A1- Dams and Reservoirs

Towards the end this research presents the development and comparison of multiple MCDM technique such as Fuzzy PROMETHEE, Fuzzy VIKOR and Fuzzy TOPSIS to as-certain an accurateness of the method in the selection of best flood control alternatives.

**7.**2 CONCLUSION

The main purpose of this study was to present a framework for flood vulnerability modeling that relies the co design and cooperation between experts. This thesis used the MCDM method as a tool to assess the flood vulnerability river region.

The finding demonstrate the merits of vulnerability assessment by engaging experts in MCDM modeling process, including criteria selection, finding the weights and then rating the alternatives.

Next the study demonstrate structural flood control model considering the experts opinion on the selected criteria. The applicable best alternative selection depends on the expert’s knowledge and expression.

It is trusted that the outcomes would give the administration, engineers, analysts, decision makers, and local authorities with a progressively suitable and invaluable guidance and outline for controlling the river basin on flooding, which is useful for managing flood Risk

7.3 RECOMMENDATION

It is possible to improve currently study by considering more and more criteria such as ecological factor, flood insurances criteria in social factor etc. this can increase the accuracy of the result.

It would be interesting to assess the future flood vulnerability study by considering climate change scenarios and future social projections. Most major urban cities in the world are expected to experience consequences of global warming in the form of more extreme rainfalls. Moreover, urban areas are expanding day-by-day, and social profile of the cities is changing rapidly. Therefore, future flood vulnerability predictions would provide significant contribution to the literature and study area.