Chapter -1

GENERAL INTRODUCTION

1.1 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 past decades, the pattern of floods across all continents has been changing, becoming more frequent, intense and unpredictable for local communities, particularly as issues of development and poverty have led more people to live in areas vulnerable to 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. Floods by nature become a complex event and caused a range of human vulnerabilities, inappropriate development planning and climate variability with the exception of flash floods, whose scale and nature are often less certain. Hence it requires more comprehensive studies about flood to formulate appropriate strategies to mitigate flood and its impacts.

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)

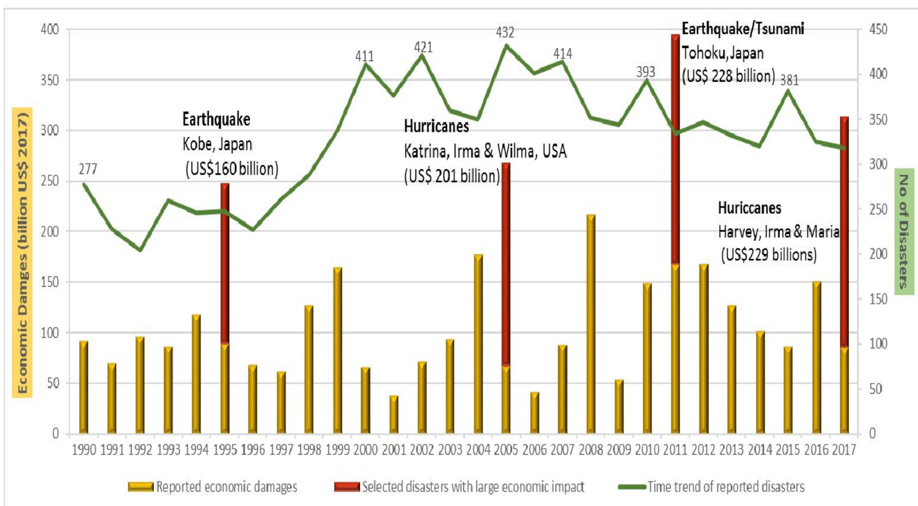

Figure 1.1 Annual occurrence and economic damages: 1990-2017

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

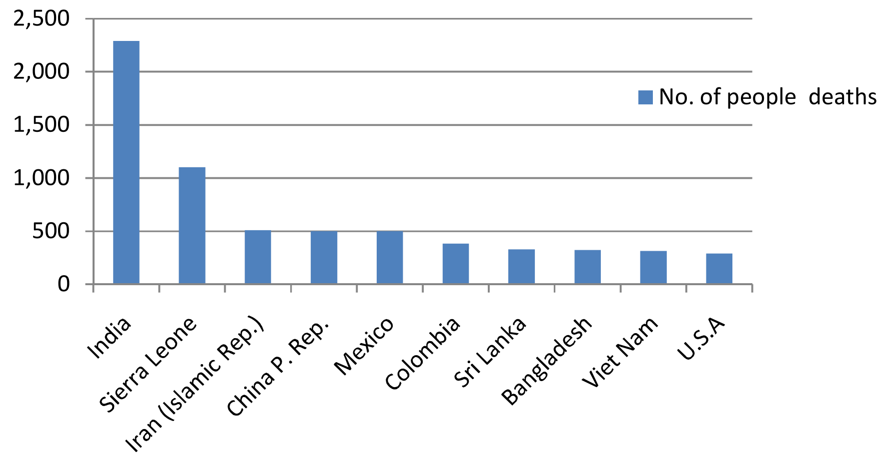

Figure 1.2 (a) No. of people deaths

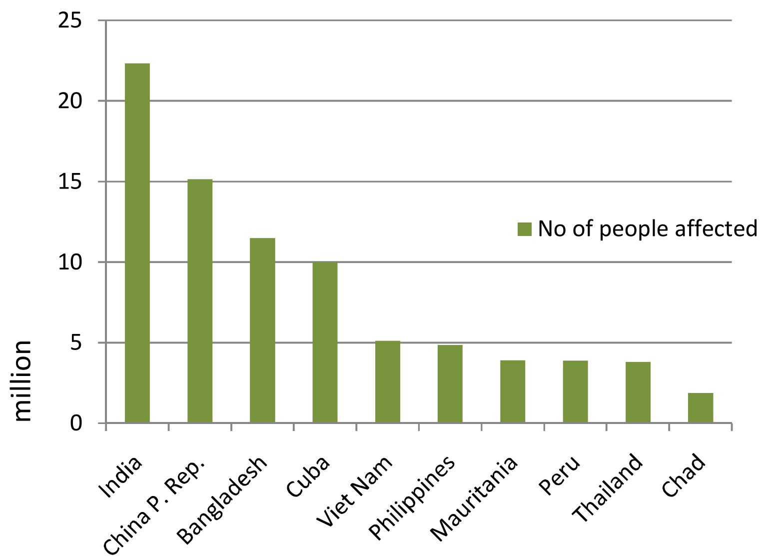

Figure 1.2 (b) No. of people affected (million)

Economic impact in 2017

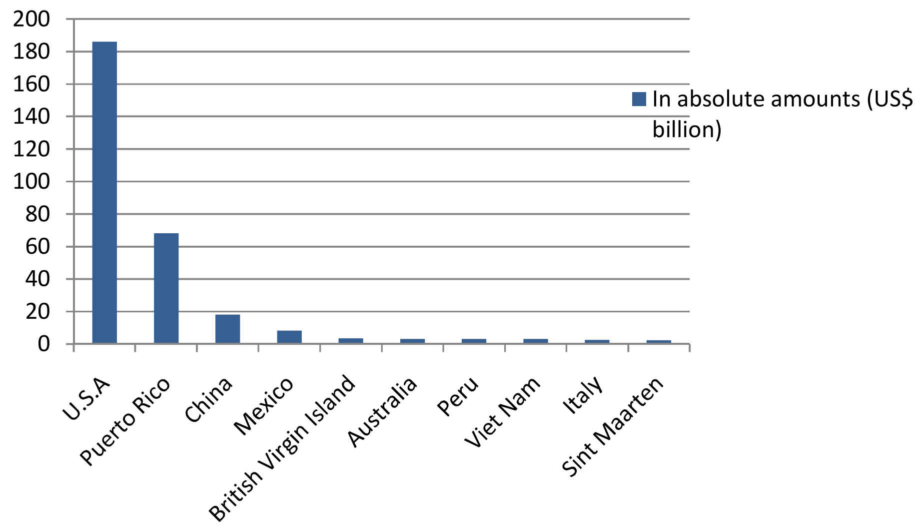

Figure 1.2(c) (10 most affected country (US $million)

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).

1.1.2 National region

India is the second largest flood affected country in the world. India has been traditionally vulnerable to natural disasters on account of its unique 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, West Bengal and Assam 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)

1.1.3 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.

1.2 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).

1.2.1 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).

$$\text{Risk=Hazard} \times \text{Vulnerability} \quad (2.1)$$

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.

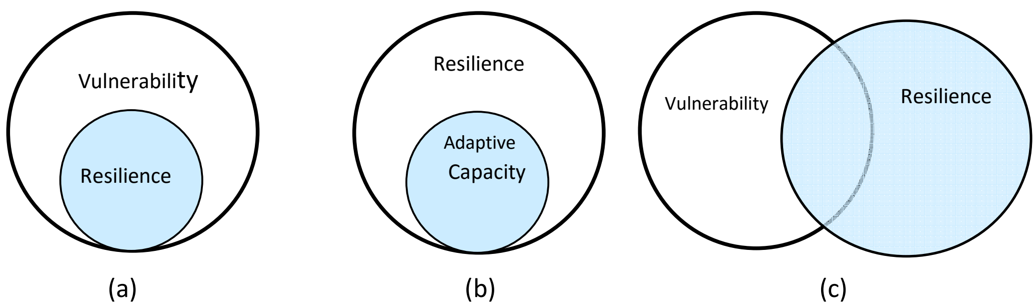

Figure 1.3. Conceptual linkages between vulnerability, resilience, and adaptive capacity according to different perspectives (Redrawn from Cutter et al., 2008)

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".

1.2.4 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.

1.3 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 views of multiple stakeholders using fuzzy set theory and fuzzy logic. Three likely response types: scale (crisp), linguistic (fuzzy) and conditional (fuzzy) are analyzed to find the aggregated input using 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 operations. First initial criteria weights are obtained and then the alternative set is evaluated, according to the characteristics of real time flood operations, operators may further modify (Jiang et al., 2009) conributed (FCA) fuzzy comprehensive assessment, simple fuzzy classification (SFC), and the fuzzy similarity method (FSM) to evaluate flood disaster risk 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 objectives of the MCDM are to find the most suitable alternatives from the different established criteria depending on the problems. (Opricovic 2007; Ju *et al*., 2013)

(Fanghua et al, 2009) discussed how to used a fuzzy multi-criteria group decision-making (FMCGDM) model Based on customized Borda scoring technique in watershed ecological risk management , a two-stage, 12-step MCDM methodology is proposed to acquire the optimal alternative decided by multiple decision-makers (DMs) from a given alternatives 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 solve multi criteria decision making problem with conflicting and non-commensurable criteria. This method is based on an aggregating function representing "closeness to the idea" which originated in compromising programming method.

(Opricovic and Tzeng, 2007) developed an approach to assess flood vulnerability using the fuzzy-based VIKOR method 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 average weights of decision makers to recognize the flood vulnerability for the reduction of the crisp data uncertainty. However, this study showed a new framework to improve the limitation of the previous study which has not considered the weight differences among all stakeholders by introducing the fuzzy VIKOR method for GDM.

(Kim et al., 2015) contributed the environmental feasibility scores of ten alternative dam construction sites based on multiple criteria VIKOR method, including landscape and geology, ecological worth, water value, and environmental toxicity, and generates sets of random numbers to fill the gaps resulting from the unfinished data.

(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 well-known methods, followed by Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), and Simple Additive Weighting (SAW). In spite of the fact 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.

1.4. 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.

1.5 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:

a) Data collection and Selection of alternatives
b) Identification of criteria
c) Formation of expert committee and opinions collection through the linguistic variable for the selected criteria and alternatives.
d) Aggregating the experts opinion using operators such as OWA and Geometric mean method.
e) Finding the criterion weights using Fuzzy AHP and F- VIKOR.
f) 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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2018 (An International Research Journal), *www.compmath-journal.org, ISSN 0976-5727 (Print) ISSN 2319-8133 (Online*

5. *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

   Some part of this chapter is published in UGC Listed Journal "International Journal of Applied Engineering Research" ISSN 0973-4562 Volume 14, Number 17 (2019) pp. 3579-358 © Research India Publications. *http://www.ripublication.com*

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