DISASTER RISK REDUCTION MEASURES IN BANGLADESH

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ABSTRACT

Disasters damage the entire economy of the country when they predominantly take place in developing countries. While no country in the world is entirely safe, lack of capacity to limit the impact of hazards has made developing countries being the most vulnerable nations to natural disasters. Bangladesh is being identified as a country that is vulnerable to climate change and subsequent natural disasters every year. Dense population and poverty has reduced the adaptability of Bangladesh in disastrous situations thus further increasing severity of impact from disasters. Owing to geographical settings, Bangladesh is currently ranked as one of the world's most disaster-prone countries in the world. The frequent natural hazards such as cyclones, storm surges, floods, droughts, tornados, riverbank erosions, earthquakes, arsenic contamination of groundwater and landslides account for significant losses in human lives and physical assets while effects are further reflected in social settings, ecosystems and the economic well-being of the country. This paper evaluates the types of natural disasters Bangladesh is subjecting to, how they have affected the Bangladesh community and existing disaster risk reduction strategies. Paper also evaluates four main domains of disaster vulnerability reduction measures namely physical, engineering, structural and organisational. Existing disaster risk reduction strategies adopted in Bangladesh are linked with the aforementioned four domains of disaster vulnerability reduction measures. A comprehensive literature review is used as the research method. Literature synthesis suggests that Bangladesh is being using a combination of disaster risk reduction measures ranging from technical to social measures.

Keywords: *Bangladesh, Natural Disasters, Risk Reduction, Vulnerability.*

1. INTRODUCTION

Natural disasters are no longer strange events for human. The entire world is facing an unprecedented scale of natural disasters and they appear to be increasing in both their frequency and intensity. The global cost of natural disasters has significantly increased in 14-folds between the 1950s and 1990s (Munich Re, 1999). 1990s and 2000s are remembered unforgettable 20 years in terms of losses occurred due to natural disasters all over the world. Japan earthquake (2010), New Zealand earthquake (2010), Italy earthquake (2009), tropical cyclone in Myanmar (2008), Kashmir earthquake (2005), Indian Ocean tsunami (2004), Bam earthquake (2003), Kobe earthquake (1995) are just a few out of that endless list of disasters.

It has been well-known that disasters damage the entire economy of the country when they predominantly take place in the developing countries. Despite the fact that the entire world is facing an unprecedented scale of natural disasters, most of the victims are reportedly from the poor developing countries (UN/ESCAP, 2006; Lloyd-Jones, 2006). While no country in the world is entirely safe, the lack of capacity to limit the impact of hazards and bounce back after major natural disasters has made developing countries being the most vulnerable nations to natural disasters. United Nations Development Programme (UNDP) reports that 24 out of 49 low-income developing countries face high levels of disaster risk and six are hit by two to eight disasters each year (Lloyd-Jones, 2006). Though only 11 per cent of people exposed to hazards live in developing countries, more than half of disaster deaths occur in these countries (UNDP, 2004 cited DFID, 2005a; DFID, 2005b). According to Moe *et al.* (2007), while Europe recorded the lowest number of victims from natural disasters, there is a higher frequency of disasters occurrence in Asia

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and the number of people who were killed and affected by natural disasters was highest in Asia. Proving the fact, Asia and the Pacific has become the world's most disaster prone region, accounting for 91 per cent of deaths from natural disasters in the past century and 49 per cent of the resulting economic losses (UN/ESCAP, 2006). There was a more than 700 per cent increase in the number of people affected due to both natural and man-made disasters in 1999 (41,244,335), in comparison to 1997 (4,698,656), in South Asia alone (IFRC&RCS, 2000 cited Ariyabandu, 2003).

Bangladesh is a South Asian country with total land area of 147,570 sq. km (Karim, 2004). It still remains a developing nation that faces variety of problems ranging from low income; lack of assets such as land and permanent housing to accommodate the people; shortages of clean water and adequate food; inability to participate in commercial activity; high population density (120 million people living in an area of 144 000 km2), human health, and illiteracy etc. (Maxwell, 1999 cited in Mclean and Moore, 2005; Ali, 1999). It has a huge population with recorded density of 855 per sq.km (Karim, 2004). All these long-lasting problems have been further exaggerated due to frequent natural disasters in the country and also have resulted in turning natural hazards into disastrous situations (Ali, 1999). Owing to geographical settings and environmental reasons, Bangladesh is currently ranked as one of the world's most disaster-prone countries in the world (Choudhury, 2002; Shimi *et al.*, 2010; World Bank, 2005) with 97.1% of its total area and 97.7% of the total population at risk of multiple hazards (World Bank, 2005). Bangladesh experiences natural disasters every year. The frequent natural hazards such as cyclones, storm surges, floods, droughts, tornados, riverbank erosions, earthquakes, arsenic contamination of groundwater and landslides account for significant losses in human lives and physical assets while effects are further reflected in social settings, ecosystems and the economic well-being of the country (Choudhury, 2002; Khan, 2008). Although Bangladesh has almost zero contribution to the greenhouse gas emission that affects global climate change, it has to suffer from the effects of climate change. Climate change is assumed to be a major force that would increase the future severity and frequency of natural disasters in Bangladesh (Khan, 2008; Ali, 1999), floods and cyclonic storm surges demand special attention because of their frequency of occurrence and damaging power (Khan, 2008). However, Ali (1999) claims that climate change is responsible for tropical cyclones, storm surges, coastal erosion, floods and droughts in Bangladesh to a greater extent.

This paper seeks to review disaster risk reduction strategies utilised in Bangladesh, in order to manage the risks of natural disasters. For the purpose of identifying the disaster vulnerability in the context of Bangladesh, natural disasters Bangladesh is at risk of and their impact on communities in Bangladesh is first discussed, eliciting evidence from past occurrences of such events. Approaches to disaster risk reduction in general are then discussed, identifying how these have been applied in Bangladesh at present.

2. METHOD

A comprehensive literature review was used as the research methodology for this paper. A key work search for natural disasters, hazards, vulnerability, disaster risk reduction, and Bangladesh was used to search literature from various sources such as electronic library data base, table of contents of journals, online journals, and e-books. Literature review was structured and presented within different categories of natural hazards and disaster risk reduction strategies used for natural hazards.

3. NATURAL DISASTER IN BANGLADESH

3.1. GENERAL OVERVIEW OF DISASTER RISKS

Current understanding is that the hazards give rise to disasters when they coincide with vulnerable populations and/or built environment structures. In other words, disasters are the disruptive and/or deadly and destructive outcomes of triggering agent(s) (in other words, hazards) when they interact with, and are exacerbated by, various forms of vulnerability (McEntire, 2001; DFID, 2005b; UN/ISDR, 2004a; UN/ISDR, 2004b). As far as the natural disasters are concerned, earthquakes, storms and torrential rains, are some of natural phenomena we refer to as 'hazards' and are not considered to be disasters in themselves. For example, an earthquake that occurs on a desert island does not trigger a disaster because

there is no existing population or property affected (ADRC, 2005). In addition to a hazard, some 'vulnerability' to the natural phenomenon must be present for an event to constitute a natural disaster. While triggering agent(s) stand(s) as the independent component of a disaster that may originate from the natural environment, human activity or a combination of the two, vulnerability is considered as the dependant component that is determined by the degree of risk, susceptibility, resistance and resilience (McEntire, 2001). The following sections discuss the past and current trends of natural hazards in Bangladesh and community vulnerability to such natural hazards.

3.2. PAST AND PRESENT NATURAL HAZARDS IN BANGLADESH

3.2.1. TROPICAL CYCLONES AND STORM SURGES

Literature and statistics on natural hazards in Bangladesh affirm that tropical cyclones are the most devastating natural disaster in the country whilst floods are rated as the second most severe in terms of the number of death toll resulted in the recorded past (Asgary and Halim, 2011; Shimi *et al.*, 2010). The peculiar geography of Bangladesh where the Himalayas in the north and the funnel shaped coast touching the Bay of Bengal in the south resulted in monsoons, as well as catastrophic ravages of cyclones, tornadoes and floods (Choudhury, 2002). Bangladesh has suffered approximately 178 severe cyclones with wind speeds of more than 87 kilometres per hour (km/h) formed in the Bay of Bengal from 1891 to 1998 and 38 severe cyclones from 1970 to 1998 (Alam and Collins, 2010). The cyclones of 1970, 1985, 1991 and 1997 are some notable events in the recent past (Khan, 2008).

Cyclones and tidal surges caused major devastations in human lives and property in Bangladesh for generations (Alam and Collins, 2010). Major cyclones in Bangladesh have claimed thousands of human lives while millions of people being affected. 1970 major cyclone has killed 500,000 people and April 1991 major cyclone was responsible for human casualty of about 140,000 lives (Choudhury, 2002). The Cyclone Sidr hit Bangladesh in November 2007 affecting approximately 30 of Bangladesh's 64 districts, claiming more than 3000 lives, approximately 53,000 people reported missing and affecting 8.7 million people (IFRC&RCS, 2010). Moreover, storm surge, an unusual rise in seawater associated with a tropical cyclone originating in the Bay of Bengal, has also caused major devastation in the coastal region (Alam and Collins, 2010).

3.2.2. FLOODS

While floods are a devastating, worldwide natural disaster, Asian continent countries such as India, China, Philippines, Iran, Bangladesh and Nepal are recognised as highly vulnerable to floods (WWAP, 2006). Among other flood-prone countries, Bangladesh is in the forefront due to frequent floods reported in every year with varying magnitudes (Choudhury *et al.*, 2004; Hossain, 2003). Almost every year floods occur in the country, but the intensity and the magnitude vary from year to year. However, reportedly, Bangladesh experiences an increasing level of flooding (Mclean and Moore, 2005). Approximately 80 per cent of the land of Bangladesh is considered as flood plain areas and about 34 per cent of its land area is flooded for about five to seven months in every year (Islam, 2004 cited Shimi *et al.*, 2010). Approximately 20 to 25 per cent of Bangladesh's territory is inundated during the monsoon season (Choudhury *et al.*, 2004; Hossain, 2003).

It is reported that that annual flooding in Bangladesh affects 20 per cent of the landmass, and in the floods of 1992 over 50 per cent was under water (ISDWC, 2002 cited Mclean and Moore, 2005). Bangladesh has experienced 29 major floods during the past 50 years (from 1954-2004), of which 11 were classified as 'devastating' and six as 'most devastating' (Choudhury *et al.*, 2004). The floods of 1987, 1988, 1998 and 2004 are some remarkable floods took place in Bangladesh in the recent past (Khan, 2008).

Annual floods bring about significant disruption to Bangladesh economic and social activities by deteriorating the normal functions of life, affecting homesteads, daily activities, water supply and sanitation condition, washing away crops, polluting groundwater stocks and destroying the vernacular mud-brick and palm-leaf buildings (Shimi *et al.*, 2010; BSHF, 2001 cited Mclean and Moore, 2005).

Extreme events result in severe floods that bring damage to affected areas where the damage is higher if the event is prolonged (Rahman *et al.*, 2005 cited Khan, 2008). While floods can are broadly classified into 'normal' and 'abnormal' or 'extreme' events (Khan, 2008), Choudhury *et al.* (2004) identify four types of floods in Bangladesh: river floods, rainwater floods, flash floods, and cyclonic/storm-surge floods. While heavy monsoon rainfalls and melting snow in the upper catchment areas of the major rivers of Bangladesh result in river floods, rainwater floods occur due to heavy rainfalls that affect floodplains and other low-lying regions (Choudhury *et al.*, 2004). Flash floods are originated from heavy rainfalls that mainly take place in the eastern and northern hill streams in Bangladesh; Cyclonic/storm-surge flooding affects the coastal regions of Bangladesh which is formed due to tropical cyclones in the Bay of Bengal and (Choudhury *et al.*, 2004). River floods and flash floods are of utmost concern to Bangladesh (Khan, 2008). Although the normal river floods together with seasonal variability in flow and water level are somewhat beneficial to the ecosystem due to carrying alluvium, extreme floods have so far resulted in severe losses.

3.2.3. DROUGHTS

Drought is a hazard closely related to climate change and it is defined as deficiency of precipitation over an extended period of time, usually a season or more, which results in a water shortage for some activity, group, or environmental sectors (Habiba *et al.*, 2010). Although it is not a frequent hazard in Bangladesh, it forms a part of the natural disaster list in Bangladesh because droughts occur occasionally causing extensive damage to crops (Choudhury, 2002). It is said that drought is a recurrent phenomenon, afflicting the country at least as frequently as major floods and cyclones (Paul, 1998 cited Habiba *et al.*, 2010). Karim (2004) reports that Bangladesh experiences drought for 7 months, from November to May, when rainfall is normally low.

Bangladesh has undergone the effects of droughts approximately 20 times in the past 50 years (Choudhury, 2002; Habiba *et al.*, 2010). There had been a severe drought in 1998-1999 dry season in some areas of the north western, south western and central parts of the country (Karim, 2004). However, the severest drought in Bangladesh had taken place in 1979 (Choudhury, 2002). Karim (2004) reports droughts taken place in 1989 and 1994-95 as well.

Bangladesh being a country largely depends on agricultural production, drought results in significant economic, social and environmental problems in the country. For example, Karim (2004) notes that the persistent droughts in north western Bangladesh in recent decades had led to shortfall of rice production of 3.5 million tons in the 1990s. Droughts being closely related to climate change, the effects of global climate change predictions indicates that the dry seasons will become drier and hotter (Karim, 2004). Mirza and Pal (1992) and Das (1997) classify droughts in Bangladesh into three groups depending on their impact (cited Habiba *et al.*, 2010):

- Agricultural drought - Shortage of moisture in the soil for crop growth;
- Hydrological drought - Falling of the surface and subsurface water levels; and decreases in stream flow, ultimately affecting soil moisture; and
- Economic drought - A condition adversely affecting the economy at large.

3.2.4. EARTHQUAKES

While history of earthquakes in the world can be traced back to centuries, Bangladesh is prone to earthquakes as it lies in the seismic zone. Specially, the northern belt of greater Sylhet, Mymensingh and the eastern part of Rangpur Districts in Bangladesh are more vulnerable to earthquakes (Choudhury, 2001). The major earthquakes that have affected Bangladesh since the middle of the last century are the Cachar Earthquake of January 1869, the Bengal Earthquake of July 1885, the Great Earthquake of July 1897, the Srimangal Earthquake of July, 1918, the Dhubri Earthquake of July 3, 1930, the Bihar-Nepal Earthquake of January 15, 1934 and the Assam Earthquake of August 15, 1950 (Choudhury, 2001). The damages caused by these shallow focus earthquakes however were restricted to narrow zones surrounding the epicentres.

3.2.5. SOIL EROSION

Along the courses of the mighty rivers in Bangladesh, the Padma, the Jamuna, the Meghna, etc. erosion every year takes away chunks of land causing displacement of large number of people and losses of properties. Due to recurrence of such erosion, displaced people are forced to come to cities for their earning. In the last 34 years submerging of river side lands are 219286 acres in Jamuna, 69135 acres in Ganges and 95119 acres in Padma. To be concerned that, erosion in the Jamuna had caused 3408 acres of land, 543 localities, 3360 metres of embankment, 5160 metres of roads, 4 educational institutions, and 2 market place already been submerged by 2007. In the mean time, the Ganges had caused 1778 acres of lands, 136 acres of localities and 570 meters of roads while the Padma had caused 1600 acres of lands, 370 acres of localities, 3930 metres of roads, 9 educational institutions, 5 market places and 1 Union Council office have been submerged in the river by recent rate of erosion (Centre for Environment and Geographic Information Services, 2000).

Some rivers in Bangladesh cause erosion in large scale and high frequency due to their unstable character. These rivers assume a braided pattern consisting of several channels separated by small islands in their courses. During the last 200 years or so, the channels have been swinging between the main valley walls. During the monsoon extensive overbank spills, bank erosion and bank-line shifts are typical. The gradual migration or shifting of channels of the major rivers in Bangladesh amount to anywhere between 60m to 1,600m annually. In a typical year, about 2,400 km of the bank line experiences major erosion. The unpredictable shifting behaviour of the rivers and their encroachments not only affect the rural floodplain population but also urban growth centres and infrastructures too.

4. DISASTER RISK MANAGEMENT SYSTEMS IN BANGLADESH

As Jayaraj (2002) describes, disaster management cannot be seen in isolation but as a collection of various phases of management in addressing this particular issue. However, there cannot be a perfect/ideal system that prevents disaster damage, because then it would not be a disaster. Disaster management is in fact a systematic process of using administrative decisions, organisation, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impact of natural hazards and related environmental and technological disasters (UN/ISDR, 2009). This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation) adverse effects of hazards (OECS, 2007). While the entire world has realised the importance of employing appropriate disaster risk management systems, Bangladesh has also been implementing various disaster risk management programmes since long time but being a poor nation, cannot manage to meet the necessary resources to proactively and reactively meet the requirements of pre and post disaster needs.

4.1. DISASTER RISK REDUCTION: GENERAL OVERVIEW

The impetus for disaster risk reduction came largely with the severe loss of life, property and ecosystems due to both natural and human induced disasters and significant climate changes. UN/ISDR (2004b) defines disaster risk reduction as "the conceptual framework of elements considered with the possibilities to minimise vulnerabilities and disaster risks throughout society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development". UN/ISDR (2009) defines the term as a "systematic development and application of policies, strategies and practices to minimise vulnerabilities and disaster risks throughout society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development". DRR entails measures to curb disaster losses by addressing hazards and the vulnerability of people to them (DFID, 2005b).

McEntire *et al.* (2010) identify four ideal types for disaster vulnerability reduction: physical science school, engineering school, structural school and organisational school. While all four types possess their own strengths and weaknesses, two are categorised as technocratic (physical and engineering school of

thoughts) and other two as sociological (McEntire *et al.*, 2010). According to McEntire *et al.* (2010) they are as follows:

- Physical science school - concentrates on living in safe areas and focuses mostly on exposure to hazards and risk reduction. This school relies heavily on the analysis of the physical environment
- Engineering school - concentrates on the built environment and ways to increase resistance through construction practices and methods of fabrication
- Structural school - concentrates on traditional notions of vulnerability more than the other three, and it stresses susceptibility based on socio-economic factors and demographic characteristics including race, ethnicity, gender, age, and other factors. This is a relatively new school of thought. The main idea is that the person is made vulnerable first and foremost due to social structure - and not necessarily by other choices they make in life
- Organisational school - stresses resilience or the effectiveness of response and recovery operations concentrates on stressing the importance of preparedness, leadership, management, and the ability to adapt, improvise, and be creative

'Organisational school of vulnerability reduction' does not assume that all disasters can be prevented and completely eliminated as the case with the other schools. This is one of the strengths of the organisational school (McEntire *et al.*, 2010). Moreover, McEntire *et al.* (2010) proposes strategies to overcome each school of vulnerability. Table 1 summarises these strategies proposed by them in reducing vulnerabilities to disasters.

Table 1: Strategies to overcome vulnerabilities (Adapted from McEntire *et al.*, 2010)

Disaster Vulnerability reduction school	Strategies to overcome vulnerabilities
Physical science school	Creation of warning systems Cautious development Environmental protection Complete relocation of vulnerable communities in extreme cases Land-use planning Careful settlement patterns General categorisation of a place's "hazardousness"
Engineering school	Ways to increase resistance through construction practices and fabrication methods Build structures and infrastructure adequately
Structural school	Improve socio-economic and demographic factors (e.g. race, ethnicity, gender, age, poverty) that usually increase a community's susceptibility
Organisational school	Effective response and recovery operations Effective preparedness Effective leadership, management, and the ability to adapt, improvise and be creative to help improve disaster activities

4.2. CURRENT TREND OF DISASTER RISK REDUCTION MEASURES IN BANGLADESH

There are a number of disaster risk reduction strategies adopted in Bangladesh in terms of reducing risk of disasters and climate change adaptation. The following sub-sections discuss the internationally recognised disaster risk reduction measures and the existing measures within the Bangladesh context.

4.2.1. FLOOD RISK REDUCTION MEASURES

Due to high vulnerability to floods, flood management in Bangladesh is considered to be crucial to poverty reduction initiatives in the country (Hossain, 2003). Both public and individual actions have been taken in Bangladesh with regard to flood risk management (Thompson and Tod, 1998). The Flood Action Plan (FAP) came into action following major floods in 1987 and 1988 with a long-term focus on sustainable solution to flooding problem in Bangladesh. The main objectives of the FAP are to: safeguard lives and

livelihoods, minimise potential flood damage, improve agro-ecological conditions for enhanced crop production, meet the needs of fisheries, navigation, communications and public health, promote commerce and industry, and create flood-free land for a better living environment (Khan, 2008). Further to that, the FAP provides guidelines for people's participation and environmental assessment for flood risk reduction (Khan, 2008).

Khalequzzaman (undated) articulates that flooding problems in Bangladesh must be analysed and necessary solutions must be taken in such a way to address three fundamental parameters called runoff, water carrying capacity, and land elevations. However, flood control measures in Bangladesh are mainly limited to building of earthen embankments, polders, and drainage (Khalequzzaman, undated). Strategies adapted by both public and individuals can be anyway classified into two groups as (Kates, 1962 cited in Thompson and Tod, 1998):

- Measure which adjust damages from floods to people (structures such as embankments);
- Measures where people adjust to floods ("non-structural" measures including flood proofing of buildings and settlements, flood warnings, land use restrictions, and adjusting crop calendars).

Since 1960s, Bangladesh government is involved in large scale flood control projects and by 1993 over 8,000km of embankments and other structures had been built at a cost of over US$5 billion (Haggart *et al.*, 1994 cited in Thompson and Tod, 1998; Khan, 2008). Loop embankments or polders have been built to protect major urban centres and coastal agricultural land while submersible embankments have been constructed for crop production and protection against flash floods in certain areas (Khan, 2008). Although certain measures like embankments and polders have been able to reduce floodplain storage capacity during floods, leading to an increase in water levels and discharges in many rivers, embankments tend to create a false sense of security among residence living within embanked areas (Khalequzzaman, undated). For example, there are several reported incidences on embankments breaching and erosion in Bangladesh such as breaching of Gumti embankment at Etbarpur during 1999 flood which caused substantial damage to the environment and property (Khalequzzama, undated). Moreover, earthen embankments can also be easily breach and can be damaged by riverbank erosion (Khalequzzaman, undated). These are evident of ineffectiveness of embankments as flood controlling measures. On top of that, adverse impact of construction of embankments is broadened to obstruction of fish migration routes and spawning grounds, and deterioration of floodplain ecosystem (Khan, 2008). Improving gravity drainage is another measure which adjusts flood extent to people (Khan, 2008). This is done through excavation and re-excavation of canals and dredging of rivers (Khan, 2008). Pumped drainage infrastructures have been constructed where gravity drainage is inadequate (Khan, 2008). Although pumped drainage infrastructure in urban loop embankments has been effective for mitigation of storm water flooding, it has not been cost-effective and resulted in channel sedimentation and adverse environmental impacts in rural flood control projects (Khan, 2008). Further to that, encroachment of storm water retention areas, obstruction of drainage routes and unplanned urban development usually weaken the effectiveness of pumped drainage infrastructure in urban areas (Khan, 2008). Construction of storm sewer and pump station is another measure adapted by the Dhaka Water Supply and Sewerage Authority to alleviate the internal drainage problems of Dhaka. The project has replaced many sections of the natural canals to concrete box culverts (Huq and Alam, 2003).

While Bangladesh government is mostly involved in taking actions to control floods, rural people are mostly keen on putting in measures to adjust to floods (Thompson and Tod, 1998). Hence, it can be argued that government of Bangladesh is using disaster vulnerability reduction measures within the Engineering school where as the community is following reduction measures within the Physical science school according to the classifications of McEntire *et al.* (2010). However, Khan (2008) claims that local people's traditional coping strategies to live with normal flood events such as river floods are far behind the required capacities to prevent, reduce and confront extreme floods. Regardless of such criticisms, it is argued that impact of flooding on households and communities are heavily reduced by flood proofing measures as well (Thompson and Tod, 1998). Flood proofing is relatively risk free and involves a minimum environmental intervention (Khan, 2008). In USA, flood proofing measure are significantly implemented through building codes as part of a set of floodplain management measures linked with

floodplain zoning and compulsory flood insurance (Thompson and Tod, 1998). In Bangladesh, flood proofing measures include building homesteads on high grounds above the flood level (Khan, 2008), modifications to existing flood prone houses (retrofitting) through measure such as raising floors of homes (Laska, 1991 cited in Thompson and Tod, 1998), minor structural and non-structural measures, public or community measures such as providing flood shelters, designing roads to be above flood level, ensuring planning takes account of flood risks, and any measures to reduce the economic vulnerability of households to flood losses (Thompson and Tod, 1998). While traditional flood proofing measures such as raising of house floors and adjustments to flooding are widely used in rural Bangladesh, there has been limited official interest in flood proofing, except development of cyclone shelters in the coastal regions, and a few flood shelters in or adjacent to the char areas i.e. active floodplains (Thompson and Tod, 1998).

Flood forecasting is another measure where people adjust to floods. There had been a significant improvement in flood forecasting accuracy and lead-time of flood forecasting in Bangladesh (Khan, 2008). Although accuracy is reasonable, the need for a longer lead-time is emphasised for better preparedness and loss reduction (Khan, 2008). On top of that, appropriate use and interpretation of the forecasting information at the local level must be ensured (Khan, 2008). These disaster vulnerability measures fall within McEntire *et al.*'s (2010) Organisational school of thought.

4.2.2. EARTHQUAKE RISK REDUCTION MEASURES

A variety of earthquake risk reduction measures are proposed by practitioners and the researchers in order to reduce the earthquake vulnerabilities of people and built environment facilities. Bangladesh should develop adequate facilities for detection and study of earthquakes (Choudhury, 2001). Reja and Shajahan (2011) emphasise the importance of adequate sustainable land use planning with seismic microzoning mapping as because the land use pattern and the physical development of the built environment all affect the intense of the effects of an earthquake. Such measures fall within the Physical school of disaster vulnerability reduction measures (McEntire *et al.*, 2010). The link between land use master planning for earthquake protection and other urban planning protection measures and the control of building quality are so interrelated (Reja and Shajahan, 2011). Satellite Remote Sensing can easily identify earth's fault zones where the earthquake mainly occurs (Choudhury, 2001). Very high resolution satellites are being used for the detection of tectonic movement of the earth (Choudhury, 2001). Further to that, seismic vulnerability maps of the buildings and earthquake prevention plan for urban areas are some other useful measures for earthquake prevention (Reja and Shajahan, 2011).

4.2.3. CYCLONE RISK REDUCTION MEASURES

Bangladesh has many programmes and projects to minimise the impacts of cyclone disasters (Asgary and Halim, 2011). Moreover, a considerable amount of studies on disaster management and related issues have been undertaken in Bangladesh with particular focus on hazard analysis, coping and adjustment strategies, and loss and damage analysis from cyclones (Asgary and Halim, 2011).

Engineering measures such as cyclone shelter is one of the key cyclone mitigation measure adapted in Bangladesh. For effective employment and management of cyclone shelters, multipurpose versions have been built in carefully selected locations, identifying uses for both normal and disaster periods (Nizamuddin, 1997 cited in Alam and Collins, 2010). Cyclone shelters demonstrate an excellent dual purpose use during non-disaster periods and cyclones (Alam and Collins, 2010).

Alam and Collins (2010) categorises cyclone adaptation strategies as pre-cyclone, during cyclone and post cyclone strategies. Pre cyclone strategies include raising the height of the plinth, planting big-branched trees around the homestead, gathering crops from fields, hiding food and valuables in the earth, setting new poles diagonally around the house, endeavouring to reach cyclone shelters and other safe places etc (Alam and Collins, 2010). Strategies during cyclones include defining the role of the local youth with regard to saving the lives of children, women and older people during surge water; using cyclone shelters; and co-existence of humans, animals and wild species in different places throughout cyclonic surge (Alam and Collins, 2010). It is evident that some of the disaster vulnerability reduction measures within the Organisation school are used during post cyclone stage. Post cyclone strategies include searching for kith

and kin and looking for housing utensils and means of livelihood, building a special tent-type of shed for those who have lost their houses, allowing women to become more active in the outside world in order to help cope with the devastation etc. (Alam and Collins, 2010).

4.2.4. DROUGHT RISK REDUCTION MEASURES

Having considered the nature and effects of droughts in the Colorado region, it is suggested that disaster vulnerability reduction measures within Organisation school improved communication and coordination between officials at the local level, as well as between the local officials and state or federal officials; and development of crisis management plans as key ways of reducing the effects of droughts (Wilhelmi *et al.*, 2008).

As far as the Bangladesh perspective is concerned, Habiba *et al.* (2010) classify drought risk management under physical, institutional and indigenous levels. At the physical level, Bangladesh Government has undertaken an irrigation project by installing deep tube wells in the region to increase agricultural productivity (Habiba *et al.*, 2010). The Barind Multipurpose Development Authority (BMDA) is actively involved in irrigating the northern district. Irrigation is necessary for many types of crops, especially for boro rice cultivation (Habiba *et al.*, 2010). There is a significant development of irrigation systems nowadays in Bangladesh compared to 1980s asserts Habiba *et al.*, (2010). At the institutional level, the Ministry of Food and Disaster Management (MoFDM) implements its mandate to coordinate all disaster management activities within Bangladesh (Habiba *et al.*, 2010). There are several of institutional arrangements have been built up from a national level to the union levels with the support of the Government of Bangladesh (Habiba *et al.*, 2010). Although Bangladesh has not yet been capable of establishing powerful institutions and systems to predict forthcoming droughts, they have established institutions at the national level such as the Space Research and Remote Sensing Organisation (SPARRSO), the Bangladesh Meteorological Department (BMD), and the Bangladesh Water Development Board (BWDB), for monitoring and forecasting disasters (Habiba *et al.*, 2010). At the indigenous level, households adopt various adjustments such as agricultural and non-agricultural adjustments (Habiba *et al.*, 2010). Agricultural adjustments include activities such as resowing crops, applying irrigation water, pond digging (Habiba *et al.*, 2010). Non-agricultural adjustments include activities such as sell and/or mortgage their land and livestock, sell their belongings to earn additional cash (Habiba *et al.*, 2010). At the community level, friends, neighbours, relatives, and affluent members may help the drought victims by providing cash, loans, food, and clothes (Habiba *et al.*, 2010) that comes under Organisation school of disaster vulnerability reduction.

Moreover, Ramamasy and Baas (2007) present various drought adaptation measures in relation to specific risks. If a few them are listed, they include re-excavation of traditional ponds; building of water control structures; check dams across the water ways; homestead gardening; mini Ponds for rain water harvesting; mango and Jujube cultivation etc.

5. CONCLUSIONS

Wide ranging impacts of natural disasters; including damages to infrastructure, built environment, and social impacts such as mortalities, highlight the importance of having effective disaster risk reduction measures in place, in order to prevent and mitigate the risks of such events. As elaborated via the review of existing literature, disaster risk reduction measures can be broadly classified as technocratic and sociological measures. Disaster risk reduction policy should entail a range of measures that best suits the context in concern and it is important that both technocratic and sociological measures are utilised therein, Availability of technocratic measures is imperative, as these physical and engineering interventions significantly contribute towards the protection of at risk communities. Sociological interventions can further limit the vulnerability of at-risk communities and enhance their resilience, coupled with technocratic interventions. Discussion on exiting disaster risk reduction measures in Bangladesh revealed that both the technocratic and sociological measures have been utilised thus far.

Although engineering and physical measures are required to prevent and mitigate disaster risk and impacts, such measures may not always be feasible due to resource constraints. Further, considering that majority of the country is at risk of natural disasters, it is inevitable that protection cannot be provided by technocratic measures alone in entirety. In this context, successful utilisation of sociological measures becomes important, in order to manage the risk of natural disasters. For example, effective management of communities, community awareness, and preparedness can play a major role in disaster risk reduction. Considering the economical and social contexts of a developing country like Bangladesh, it may be argued that there is scope for further utilisation of sociological measures for disaster risk reduction. Especially when it comes to a country like Bangladesh with a developing economy, community can be considered as a strength in addressing risks of disasters. Therefore, it can be argued that strengthening the social dimensions would lead towards better disaster risk reduction activities. Although the country may lack in physical and engineering related disaster risk reduction measures; use of the strengths of community can be better used to organise and act promptly and effectively during disastrous situations.

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