Chapter 11
Climate Change Adaptation in Urban Areas: A Critical Assessment of the Structural and Non-structural Flood Protection Measures in Dhaka

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Abstract Dhaka, the capital city of Bangladesh, is susceptible to floods because of its topography, large population, and inadequate infrastructure. Almost half of Dhaka's population live in the low-lying and flood-prone areas, and the local communities suffer from economic stress due to flooding as well as having an absence of flood protection measures in these areas. The economic damages caused by flooding have a severe impact on national economic development and growth. Unplanned urbanization intensifies damage from flood incidents, including caused by the migration into Dhaka from rural areas as people move to the city in search of jobs and to recover from the impacts of natural disasters like cyclones, droughts, and river erosion in rural areas. This chapter outlines Dhaka's current situation with regards to flood exposure and risks from climate change as well as summarising key measures to reduce flood risk in recent years.

Keywords Urban · Climate · Protection · Dhaka · Flooding · Exposure Risk

11.1 Introduction

Bangladesh, due to its vulnerable geographical location, high population density, poor infrastructure quality, and unstable economic and political situation, is considered one of the most vulnerable countries in the world to climate change and climate-induced hazards. Among the climatic perils, flooding (because of its extent and damage potential) poses a significant threat to people. Dhaka, the capital city, is particularly susceptible to floods because of its topography, large and growing population, and inadequate infrastructure. Dhaka is also the center of Bangladesh's

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administrative, educational, economic and social activities, and any damage and impediment to the city's functions can threaten the country's overall economy. Therefore, this chapter reviews and evaluates flood protection measures for safeguarding Dhaka. Firstly, it outlines Dhaka's current situation concerning flood exposure and risk from climate change. Secondly, it summarizes several measures to reduce flood risk and damage undertaken in recent years, and thirdly, it evaluates the performance of these actions.

Dhaka is surrounded by various water bodies, namely the Buriganga River to the south, Balu River to the east, Tongi Khal to the north and the Turag River to the west (see Huq and Alam 2013). These rivers are distributaries of three major rivers, the Ganges, Brahmaputra, and Meghna, which form the flat deltaic plain. Dhaka is at the center of this flat plain (Bala et al. 2009). The Dhaka Metropolitan (DMP) area is approximately 304.16 km^2, and the total population of the area is around 14 million (Dewan 2013). The city is divided into Dhaka East and Dhaka West. Embankments surround the western part, but dam construction in the flood plains of the east remains under consideration (Dasgupta et al. 2015).

Almost half of Dhaka's population live in the low-lying and flood-prone areas, and the local communities suffer from severe physical, social and economic stress due to flooding, water logging, and drainage congestion. The absence of flood protection measures makes the eastern part more flood-prone, and the whole city vulnerable to flood hazards (Haque et al. 2010). Flooding also causes severe environmental problems such as contamination of drinking water, riverbank erosion, and mosquito infestation.

Dhaka has experienced several flood incidents due to the overflow of the encircling rivers. This excess runoff is exacerbated by unmanageable upstream flow, the unplanned and congested city fabric and unpredictable climate. The city has already experienced significant floods in 1954, 1955, 1970, 1974, 1980, 1987, 1988, 1998, 2004 and 2007. The 1998 and 2004 floods were catastrophic, taking into account the extent of affected areas and duration of waterlogging. In both years, a significant portion of the city was inundated, and more than 50% of city dwellers were severely affected. The impacts were higher among the poorest segment of the population, including day-laborers, rickshaw pullers, slum dwellers and the homeless.

The total economic cost of the floods in 1988, 1998 and 2004 was US$11.16 million, US$4.4 million and US$5.6 million respectively (Dewan 2010; Gain et al. 2015). Being a developing country where almost one-third of the population live below the poverty line, such huge financial loss has implications for economic growth and development progress. According to several studies, Dhaka is still under severe threat from urban flooding due to the impacts of climate change (Bala et al. 2009; Gain et al. 2015; Dewan 2013). Flood mitigation measures are therefore essential to address the economic, social and environmental impacts of urban flooding.

11.2 Flood Risk in Dhaka

According to the framework used by Gain et al. (2015), the overall flood risk of the city depends on three factors: the intensity and frequency of the "hazard", the "exposure" of the elements such as people, infrastructure, agriculture and others and the "vulnerability" of the exposed elements (see Gain et al. (2015) and Mojtahed et al. (2013) for flood risk assessment techniques in urban areas). Risk can be understood as a result of the interaction between hazard, exposure, and vulnerability (IPCC 2014). A hazard is the potential of a natural or human-induced event to occur that could result in loss and damage to assets such as infrastructure, property, livelihoods, provision of services and environmental resources in addition to injury, loss of life or other adverse effects on health (IPCC 2014). "Exposure" refers to the presence of resources, assets, livelihoods or people in areas or settings that could be adversely affected by a hazard (IPCC 2014). Finally, vulnerability, as defined by the IPCC (2014), is the propensity to be adversely affected, including the "sensitivity to harm", by the exposed elements and the "capacity to cope and adapt".

The high intensity of flood hazard in Dhaka depends on two factors. First, the overflow from surrounding rivers results in flooding almost every year. The upstream flows from improperly managed trans-boundary water sources escalate this problem (Mozumdar 2005). The second factor is the extreme rainfall events that have increased in frequency and magnitude over the last decade due to the effects of climate change (Murshed et al. 2011). Dhaka receives around 2000 mm of rainfall each year, and 80% of this occurs in the monsoon season, thus increasing the probability of flooding (Dewan 2013). Rain events have become unpredictable and erratic due to anthropogenic climate change that can increase the intensity and frequency of hazards, thus heightening overall flood risk in Dhaka (Alam and Rabbani 2007).

The unplanned urbanization across the city also intensifies damage from flood incidents. Massive rural to urban migration by people in search of jobs and to recover from the impacts of natural disasters like cyclones, droughts, and river erosion has increased the demand for housing and essential services in the city. Each year around 500,000 people migrate to and settle in Dhaka city (Cities Alliance 2016). Many illegal slum and squatter settlements are constructed to create accommodation for this growing population, and it is done in an unplanned way, bypassing planning regulations, which are facilitated by local political leaders and middlemen (Morshed 2013; Kabir/Parolin 2012). According to Dewan/Corner (2012), the total urban land area of Dhaka city has increased 67% from the 1990 levels (from around 116.20 km^2 in 1990 to 194.07 km^2 in 2011). Griffiths et al. (2010) also demonstrated the rapid urbanization of the city with most growth occurring in the unprotected eastern part where, due to the lack of an embankment, flooding happens more frequently. The study also predicted that migration towards Dhaka would increase due to the impacts of climate change. Problematically, the greater the migration into the city, the greater the exposure to flood risks, especially for low-income residents living on marginal, flood-prone land.

The third factor that increases the risk of flood impacts in Dhaka is the unsafe conditions of infrastructure. The infrastructure facilities (such as roads, drainage systems, buildings, etc.) in most of the city are inadequate and prone to damage from flood incidents (Braun/Aßheuer 2011). Also, the high population density of the city increases the probability of harm from flood events. Approximately 40% of the total population in Dhaka live in slums that are built in flood-prone areas (Dewan 2013) with very basic infrastructure and unhygienic living conditions (Rashid et al. 2007). The poor socio-economic conditions of most of the city dwellers reduce their coping capacity to flood events and result in damage to their shelters, health, and economic conditions.

The overall flood risk in Dhaka is expected to increase, due to the effects of climate change. It is anticipated that the frequency of extreme rainfall events in Dhaka city could increase 16% by 2050 (Dasgupta et al. 2015). Another analysis also showed that return period of extreme flood events is lessening (which means that extreme events are becoming more frequent) (Dasgupta et al. 2015). The planned improvements to the drainage system of Dhaka city may still lack the capacity to handle such large rainfall events and contribute to the overall flood risk.

11.3 Stakeholders and Measures of Flood Risk Management

At present, the management of flood control measures is the combined responsibility of several organizations (Table 11.1), which might create a jurisdictional impediment. In the past, lack of coordination between stakeholders resulted in a bad management of the culverts and regulators during the 1998 flood (Bala et al. 2009). Dewan (2013) noted that organizations tend to blame each other for critical failures, and are sometimes unwilling to take responsibility for the damage. However, during the 2004 flood, Bala et al. (2009) observed that the level of coordination improved and, as a result, the flood situation was managed more efficiently.

Table 11.1 Stakeholders in flood risk management in Dhaka

Organizations	Responsibility
Ministry of finance	Allocating the budget for flood control measures
Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC)	Controlling the smaller underground and surface drains within their jurisdiction area
Dhaka Water and Sewerage Agency (DWASA) and Bangladesh Water Development Board (BWDB)	Operating and maintaining the embankments around the city Looking after the larger open drainage canals and pipes
Capital Development Authority (RAJUK)	Installing underground drainage lines during road construction

Source The authors

Existing methods for flood mitigation are traditionally divided into two broad groups: structural and non-structural measures (Dasgupta et al. 2015). Structural measures, according to the definition of the United Nations International Strategy for Disaster Reduction (UNISDR 2015), include physical constructions that aim to mitigate potential hazardous impacts or the application of engineering techniques to achieve hazard-resistance and resilience in structures or systems. In contrast, non-structural measures are those that do not involve physical construction but use knowledge, practice or agreement to reduce risks and impacts, in particular through 'policies and laws, public awareness raising, training and education' (UNISDR 2015).

Andjelkovic (2001) views structural measures as the more conventional method of protection in the form of dams, storage reservoirs, dikes, floodwalls, flood diversion, channels and land treatment practice. Non-structural methods, on the other hand, include 'preparedness, response, legislature, financing, environmental impact assessment, reconstruction and rehabilitation planning' and can contribute directly towards reverting the damage potential of flooding by giving people more strength for post-disaster recovery (Andjelkovic 2001).

11.4 Structural Measures

Buckland Bund was the first ever embankment constructed in 1864 on the northern bank of Buriganga River to protect Dhaka from flooding and river erosion. The need for flood mitigation measures arose after the 1954 and 1955 disastrous floods in the country (Huq and Alam 2003). As a result of these floods, the Master Plan of 1964 was prepared and some significant flood mitigation studies were conducted (Mozumder 2005). While plans for flood protection were under consideration for Dhaka, the pressing need for immediate action arose after the 1987 and 1988 floods. At this time, the Government of Bangladesh initiated a two-phased immediate flood protection and drainage project, "Greater Dhaka Flood Protection Project (GDFPP)", that included enclosing the DMP area with flood embankments, reinforced concrete walls, and providing drainage and flood regulation structures such as sluices and pumping stations. Phase-I was completed in 1992; with a 136 km dam surrounding the western part of Dhaka city (Chowdhury 2003). Alam and Rabbani (2007) identified the following key components of the flood protection measures:

- Approximately 30 km of earthen embankment along the Tongi canal and the Turag and Buriganga rivers
- About 37 km of raised roads and floodwalls
- A total of 11 regulators along the embankment at the outfall of khals (canals) to the surrounding rivers
- One regulator and 12 sluice gates on the khals at the crossings with the Biswa, DIT, Pragati Sarani and Mymensingh roads and the railway line at Uttar Khan

- One pumping station at the outfall of the Kallyanpur khal into the Turag River and another at the outfall of the Dholai khal to the Buriganga River. These pumping stations are for draining rainwater from parts of Dhaka West, and
- A special 10.53 km embankment surrounding the Hazrat Shahjalal International Airport.

Phase-II is yet to start but will surround the city from the eastern fringe with a rail/road embankment that will run for 29 km along the Balu River. Though these flood control and drainage works saved Dhaka west from flooding to some extent, during the 1998 flood, the embankment could not serve its intended purpose due to improper planning. Its height was not enough to contest a flood like the one in 1998. Furthermore, some open culverts[1] and unclosed regulators of the embankment facilitated water intrusion from outside. The embankment worked well during the 2004 and 2007 floods, but the condition of the protection bunds has degraded as settlements have increased and encroached onto them (Bala et al. 2009).

Subsequently, the embankment has brought about significant social, land use and environmental changes in the surrounding area. Agriculture lands in the fringe have been converted to residential areas. Dumping of solid waste and agricultural residue disrupts the area's natural beauty. Groundwater quantity and quality have also been reduced to a great extent. Low-income residents are also being forced to build squatter and slum settlements in these areas, exacerbating flooding problems outside and inside the city by impeding the existing drainage system.

During the monsoon, the higher water level of the rivers reduces drainage capacity, reducing their ability to accommodate the city's surface runoff (Dewan 2013). At the same time, continuous rainfall increases the surface water runoff in the city, and demand for surplus rainwater drainage increases. The reduced water bearing capacities of the river along with the inadequate drainage infrastructure creates internal flooding and waterlogging. To alleviate the problem, DWASA undertook a storm water drainage improvement plan that ensured the proper flow of the city's water bodies by constructing concrete box culverts (Huq/Alam 2003). Another measure was the banning of polyethylene bags to reduce drainage system congestion (Alam/Rabbani 2007). Dhaka has approximately 40 canals and some ponds that act as retention and detention areas. The canals are linked with the river network and create a drainage system. Many of these canals and lakes are no longer effective due to illegal encroachment or acquisition for the construction of buildings (Bala et al. 2009). Mahmud et al. (2011) show the spatial extent of wetlands in Dhaka city over last few decades, with a significant decrease between 1988 and 2009. The loss of wetlands impedes the natural drainage system of the city and thus increases flood risk.

There are 3 large and 66 small pumping stations to reduce inland water congestion; those functioned well until the 2007 flood. Additionally, there are 185 km of drainage pipes under the city to drain storm water (Bala et al. 2009). Dhaka can sustain medium sized rainfall events (200–250 mm/day), with a peak intensity of

[1]A culvert is a drain or pipe that allows water to flow under a road or railway.

approximately 100 mm/h, whereas additional infrastructural improvements are needed to cope with larger rainfall events (exceeding 300 mm/day) (Dasgupta et al. 2015). The analyses of rainfall data for Dhaka have shown that the return period of extreme rainfall events is lessening, and 100-year rainfall events like the one in September 2004 (341 mm/day) will likely become more common in the future due to climate change. For example, heavy and persistent rainfall in June 2015 submerged parts of Dhaka for a long time and caused suffering for many city dwellers (The Daily Star 2015). Although the structural measures provided some protection from flood incidents, they faced many problems relating to their effectiveness and function during extreme rainfall events. This most recent example clearly indicates that we are not prepared for the unforeseen climatic events that might disrupt the whole city fabric.

11.5 Non-structural Measures

Non-structural measures should be an integral part of urban flood management along with the structural options to reduce damage and enhance effective response. In the case of Dhaka, it is evident that traditional structural measures are not sufficient for guaranteed flood protection (Faisal et al. 1999). Over time, the focus has shifted towards non-structural options. The following section will highlight some of the non-structural methods implemented in Dhaka. Many of these measures were proposed after the catastrophic flood in 1998 (Faisal et al. 1999).

11.5.1 Creation of Flood Zones and Building Regulations

According to the definition of the Bangladesh National Building Code (BNBC) standards, if a zone has the possibility of getting flooded with a water level of one meter or more, it is considered a flood-prone area. The code recommended that any building constructed in those areas should have the lowest floor above the flood zone (Mozumdar 2005). The Detail Area Plan (DAP) of the Dhaka Metropolitan Development Plan (DMDP) and the Urban Area Plan (UAP) of the city also have precise demarcation of flood flow areas. The flood flow zones demarcated by the DAP restrict possibilities of any future large-scale development (Morshed 2013).

The zoning of flood-prone areas and land-use restriction implemented by RAJUK through the DAP should work as an effective measure towards keeping people away from flood incidents. However, much of the low-lying areas of the city (considered as wetlands) are encroached upon due to the overwhelming population needs (Braun/Aßheuer 2011). A significant portion of these developments is being constructed by housing developer agencies, which violates many regulations. However, through financial and political backup these agencies are building housing that will effectively nullify the implication of DAP as a flood mitigation policy (Morshed 2013). In addition to the construction made by land developers, illegal slums are being built which are at high risk from flooding due to their exposure and inherent vulnerability (poorer residents are vulnerable due to lack of stable jobs and financial crisis). An active zoning policy might include restricting these illegal settlements and relocating people into flood free areas. Box 11.1 outlines flood vulnerability of slum dwellers, their preferences, and relocation options.

Box 11.1: Slum Dwellers' Relocation Preference. *Source*: The authors.

This study conducted by Rashid et al. (2007) aimed to formulate a preference model chosen by slum respondents if they were asked to relocate to flood free zones. The central hypothesis of the study was that if the slum dwellers in case study areas were given economic incentives, they would relocate to flood free areas.

The study was based on an in-depth questionnaire survey conducted in two areas in Dhaka city: Mirpur and Vasantek . The survey respondents were selected through a systematic approach, with 200 respondents from each of the slums.

The findings of the survey were grouped into three categories. The first is how the respondents assess the flood problem. The result shows that most people have faced some level of damage during a flood incident, and the situation is worse in the Vasantek area. The second is the socio-economic conditions of the slum dwellers, many of whom migrated from rural areas, and work as factory laborers or rickshaw pullers. In both locations, they faced infrastructural and political impediments. The third finding is that the population of these localities would only relocate from the current position to a flood free zone if they were given several economic incentives such as flood-free land at no cost, employment opportunities, grants, and loans to relocate to the new site. If these incentives were not present, then the residents were not willing to move.

The study also revealed that the local people are strongly tied to their current location, despite harassment from government agencies and local extortionists. Therefore, the case study concluded that it would require significant economic and structural incentives to relocate people, and sometimes it might be more efficient to improve on-site coping strategies such as in-situ upgrading of slums through the provision of infrastructure, water supply and sanitation, and management of pollution in the slums.

11.5.2 Flood Forecasting and Warning

Flood forecasting and warning systems are efficient ways to reduce the damage resulting from flood incidents (Dasgupta et al. 2015). The Flood Forecast and Warning Center (FFWC) of BWDB provides live daily updates of river water levels at different points throughout the country and disseminates the information when it goes above the danger mark. In Dhaka, the forecast and warnings are mainly calculated and distributed for river water flooding.

Although the center generates regular forecasts, the technical expertise remains limited and the information and warning messages are confusing for local people to understand. The messages from the monitoring station are primarily designed for decision makers and flood experts, making it difficult for non-technical or illiterate persons (especially residents in the slum areas) to respond. Also, with a lack of understanding of the potential impacts of different water depths, people find it difficult to take protective measures. The warning information only provides the water depth of the rivers but they do not give any spatial reference; thus people find it hard to adapt.

11.5.3 Flood Shelter

Dhaka experiences inundation each year due to river flooding in the eastern part of the city and water logging caused by drainage congestion in the west (Bala et al. 2009). This constant inundation is creating the need for flood shelters to provide temporary accommodation for the affected people. Most of the shelters in Dhaka are built on an ad hoc basis after the flood incidents (Maniruzzaman/Alam 2002) and are not planned and duly designated or maintained like the rural ones; this might create severe problems in emergency evacuation and management during sudden and long-term flood incidents (Masuya et al. 2015). Information about the limited number of designated shelters is also not well disseminated, thus crippling the emergency operation. In a recent study, Masuya et al. (2015) conducted a spatial analysis of plausible flood shelters in the city and their proximity to vulnerable residential areas (summarized in Box 11.2). The result verifies the importance of the flood shelters in Dhaka.

Box 11.2: Potential Location of Flood Shelters in Dhaka City

The case study was designed to achieve three objectives: to show the spatial distribution of potential flood shelters in the city of Dhaka, to identify vulnerable housing units, and to assess the potential of these flood shelters in terms of their ability to save the people during disasters. The study was conducted by Masuya et al. (2015) in a subset of the Dhaka Metropolitan Development Plan (DMDP) zone.

First, the survey team developed a raster map of the case study area and assigned a flood rank for each of the cells, thus creating a flood hazard map for the area. The rank was allocated according to flood frequency and flood depths. The team then identified the potential flood shelters and vulnerable households. The flood shelters were selected by building type, number of stories, and distance from the flood hazard. On the other hand, the vulnerable families were chosen by the structure type of their home and their location with respect to flood hazard intensity. Finally, the study calculated the average number of people to be saved by the potential flood shelters.

The result of the analysis is described in three segments. According to the spatial distribution of the flood hazards in the city, the eastern side is located in the high hazard zone. The analysis also reveals that around 60% of the study areas fall under hazard zones, with 45% classed as highly hazardous. The second part of the analysis identified 5537 buildings that can be used as flood shelters of different sizes. The distribution of these shelters was shown (Masuya et al. 2015) in conjunction with vulnerable households of five catchment areas, indicating how many households have access to the shelters. The results suggest that none of the catchment areas have enough shelters for the overall vulnerable population.

The implications of the study are significant as they can help improve the emergency evacuation plan for Dhaka city during a flood. However, more research is needed to assess the condition and capacity of the potential shelters.

11.6 Conclusion

Flood risk implications should be embedded into city planning processes as flood damage costs are significantly high. As discussed, flooding poses a significant threat towards Dhaka, and the city lacks the proper mechanisms to counter it. The structural flood protection measures are in a poor condition. The embankment to the west of the city lacks adequate and continuous maintenance. The eastern part of the city still does not have any physical protection from flooding. The city also lacks the ability to counter illegal encroachment and land acquisition around the dam and low-lying areas, which reduce natural water drainage. The housing and commercial developments do not follow proper regulation, and there is a lack of adequate communication regarding flood risk and the need for well managed and equipped flood shelters. All these factors increase the vulnerability of the city and decrease the ability to cope with extreme flood events.

The large-scale climatic and economic migration from all over Bangladesh creates significant pressure to land availability in the city and forces people to live in the low-lying, flood-prone areas. Many of these settlements also do not have any legal rights, and thus these groups need special attention in the overall flood management scenario. In short, the flood risk in Dhaka is a combined result of its climatic and geographical conditions and its weak political and economic capacity to address the situation.

As a result, improvements in both structural and non-structural measures are needed to counter the risks posed by flooding in Dhaka. The eastern part of the city has to come under the protection of a flood embankment. In addition, proper maintenance and monitoring of the embankments must be ensured. Having a long-term financial mechanism in place is also a critical factor. As several organizations are involved in the overall management process, perhaps an umbrella organization mainly designed for flood risk management can be created to ensure multi-stakeholder coordination. Stronger legal enforcement and political willingness are required to recover illegally occupied canals and river banks.

An effective early warning system is needed to ensure that people have enough time to prepare for any upcoming flood events. The warning messages should be clear and disseminated properly. Each ward and community in the city should have a flood management committee to help local people understand the implications of such disasters. Flood shelters should be created throughout the city, particularly close to the flood-prone areas where most of the migrated, low-income people live. These shelters should be managed well with the participation of each community and ward.

Finally, Bangladesh has several national level strategies, such as the National Plan for Disaster Management, National Adaptation Programme of Action (NAPA) and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) to address the climate change and disaster situation. However, these policies lack specific guidelines for Dhaka and other urban areas. A tailored management system based on the national strategies is needed to achieve effective flood risk mitigation (in Dhaka), which will include the reduction of hazard exposure and improvement of the overall coping capacity of vulnerable communities.

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