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Thesis

Title: *Climate change adaptation assessment: A case of the Eastern fringe of Dhaka, Bangladesh*

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UMD 6

Executive Summary

Climate change is the major threat of this time posing severe stress to the human being and also to the environment. The effect is global and unprecedented. It is projected to be continued to take place over the next century even after undertaking effort of lessening the GHG emissions. And the least developed countries are most at risk lacking in capacity to shield their cities.

Bangladesh is stated to be one of the twelve countries most at risk for climate change. Bearing the fact the Bangladesh's contribution to GHG emissions is one of the lowest in the world, even though it is at high risk because of its disadvantageous geographic location, high population density, low topography. Dhaka, the capital of Bangladesh, is one of the largest mega cities of the world with a very high rate of urbanization. Climate change poses risk to Dhaka mainly through flooding. Though flood has a long history in this country, but it is exacerbated by the climate driven variability.

The study area, Eastern fringe of Dhaka is the low lying area of Dhaka city. It forms two thirds of Dhaka's drainage basin. According to structural plan, it is stated as flood flow zone. But in the process of urbanization, wetlands are being encroached causing major water clogging leading to flood. Moreover, the drainage system is not improved in pace with the high rate of urbanization. The study area has faced severe damages during several catastrophic floods in last few decades, almost the whole EFA was inundated. Dhaka West is protected, but Dhaka East, which is most at risk, is still unprotected from flooding. Though there are proposed measures to be undertaken for reducing the vulnerability of Dhaka EFA, it is still not being implemented. Therefore, the research aims to investigate the vulnerability of the Eastern fringe of Dhaka to flooding and to assess and prioritize the most effective adaptation measures to the risks of flooding for the area. In this study, climate change has been considered not only as an environmental problem but also a developmental issue.

Theoretical concepts related to the topic have been analyzed by reviewing relevant literatures. Different adaptation planning approaches, adaptation strategies and prioritization methodologies have been studied as well to find out the appropriate one for the research. This qualitative exploratory research holds the strategy of holistic case study. The unit of analysis is the study area itself. The research is based on both primary and secondary data. Primary data has been collected by questionnaire survey, experts' judgment, focus group discussion and direct observation. Purposive sampling method has been adopted for selecting the experts and stakeholders, and sample inhabitants of the study area for questionnaire survey have been selected using random sampling method. The data analysis methodology applied in this research is 'Multi criteria analysis' which is also suggested by UNFCCC adaptation framework for LDCs.

To meet the objective of investigating the vulnerability of the study area, vulnerability assessment has been conducted. Vulnerability is an accumulated outcome of three aspects, exposure, sensitivity and adaptive capacity. Therefore, to investigate the vulnerability, exposure index of the study area to different types

of flooding hazards have been identified based on the secondary data on the frequency, duration and spatial extent of different types of floods. It shows EFA is most exposed to riverine flooding. Sensitivity index has been prepared based on the impacts of floods in the study area from last three decades. It is found that water quality is the most sensitive sector of EFA to flooding. To identify adaptive capacity, survey has been conducted to identify the factors which determines adaptive capacity; i.e. demographic characteristics, occupation, education level, income level, existing infrastructure services of the study area. Taking into account, the dominant group in each considered factors for adaptive capacity and equal access to the existing infrastructure services, it has been assumed that the whole study population bears the same adaptive capacity. Vulnerability index, prepared based on the above mentioned three indices, shows that water quality is the most vulnerable capital asset of the study area to flooding. Infrastructure and trade are also extremely under threat to flooding.

All the existing proposed adaptation measures (i.e. flood embankment, construction and up gradation of storm sewer/drainage system, flood wall, raised road, protection of water retention areas and canal improvement) have been taken into account for assessment. And also based on the vulnerability assessment, two additional measures (i.e. enhancing emergency response mechanism and early warning system) have been selected from the relevant cases bearing similar context. Criteria to assess adaptation options are selected in a participatory way by the selected stakeholders of the study area as consensus through FGD. The main aspects to be considered during the assessment of adaptation options are decided by the stakeholders to be as follows: vulnerability, financial, environmental, socio political, macro economic, socio economic, institutional and technological aspects. The criteria resulted from the discussion under these aspects are vulnerability reduction, cost, enhancement of ecological condition, pubic and political acceptance, employment generation, achievement of MDG, institutional and technical capacity.

The selected experts scored each adaptation option against the selected criteria. To ensure stakeholders' preferences in the process, weighting of each criterion has been done by the same stakeholder group. Thus, this interactive weighting method has been proved to be an effective way to legitimate the outcome. Then the expert score is combined with the weights of the criteria to get the final score. The prioritization of adaptation options is done based on this final score. It is found that 'Protection of water retention area' is the most effective option to be undertaken to reduce the vulnerability of the EFA to flooding. 'Enhancing early warning system' and 'Canal improvement' is also identified to be very effective options, flood wall is found to be the least effective one. Sensitivity analysis is conducted to test the robustness of the result and incorporate the uncertainty and range of stakeholders' preferences. It shows the results are quite robust with regard to the criteria weights. The research concludes by putting forward the scope for further research.

Key words: *Climate change, Adaptation assessment, Flood and vulnerability, Prioritization, Multi Criteria Analysis.*

Dedication

To my family

for

……. All that I am or all that I ever hope to be …….

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List of abbreviations

APF	Adaptation Policy Framework
BWDB	Bangladesh Water Development Board
CBD	Central Business District
DMDP	Dhaka Metropolitan Development Planning
FAP	Flood Action Plan
FFWC	Flood Forecasting and Warning Center
FGD	Focus Group Discussion
GHG	Green House Emission
GoB	Government of Bangladesh
IHS	Institute for Housing and Urban Development Studies
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
LDC	Least Developed Countries
MAPA–DST	Multi Actions Prioritization Analysis and Decision Support Tool
MCA	Multi Criteria Analysis
MDG	Millennium Development Goal
NGO	Non Governmental Organization
NAPA	National Adaptation Programs of Action
SPZ	Spatial Planning Zone
RHD	Roads & Highways Department
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change

Glossary of terms

Adaptation to climate change	Any action undertaken to lessen the vulnerability of a system, population or individual to the unfavorable effects of climate change.
Adaptive capacity	The system's ability to cope with climate variability and climate extremes as well as to restrain probable damage.
Adaptation assessment	The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, and feasibility.
Climate change	A change in the state of the climate that can be identified by changes that persists for an extended period, usually decades or longer.
Exposure	The exposure of a system to stimuli that act on that system.
Flash flood	Flood that occurs all on a **s**udden, may be caused by storm, heavy rain, collapse of dam or for many other reasons.
Multi-criteria analysis	Any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives.
Rainfall induced flood	Caused by excessive runoff due to rainfall.
Riverine flood	Caused by overflow of river when the water exceeds the capacity of the river.
Sensitivity	Responsiveness of a system to climatic variability and the extent to which this responsiveness might be affected.
Storm water flood	Flood caused by excessive rainfall or storm within short period of time.
Storm surge flood	Flood caused by offshore rise of water during storm.
Vulnerability	The degree to which a system is prone to be affected due to the exposure to hazards.
Vulnerability assessment	The process of identifying and quantifying the vulnerability of a system.

Table of Contents

List of Tables

List of Figures

List of Boxes

"Just as human activity has caused the problem of climate change, so too can human activity find the solutions."

Francis Gurry,
Director General,
World Intellectual Property Organization,
United Nations

Chapter1: Introduction

Chapter 1 provides a background of the study giving emphasis on the climate change scenario in the context. This Chapter puts forward the problem statement and rationale of the study along with the research objectives and questions with an intention to provide an understanding of the focused topics that will be addressed in the research.

1.1 Background of the study

It has been projected that despite of the effort to lessen green house gas emissions, climate change will continue to take place over the next century. This will even exacerbate existing environmental problems in many counties, mostly in the least developed countries which do not have the capacity to shield their cities. The diversified surveillance of sea level rise, increased precipitation, melting of glaciers, storm surges, heat waves, increased ocean water temperatures make the effects of climate change unequivocal. More specifically, eleven of the last twelve years (1995-2006) rank among the 12 warmest years ever recorded since global surface temperatures are measured (1850). Over the last 100 years (1906–2005), global temperature has increased by 0.74°C[1]. Global average sea level rose at an average rate of 1.8 [1.3 to 2.3] mm per year over 1961 to 2003. In 2007, the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report predicted that by 2100, global warming will lead to a sea level rise of 19 to 58 cm[2].

There is a global inequality between those cities who are causing climate change and those who are at high risk from its effects. These cities under high risk, which hardly contributes to the overall green house gas emissions, still have to undertake adaptive measures. These countries are mostly the developing countries which have an enormous backlog in the basic infrastructure services to protect their cities.

A recent World Bank report lists Bangladesh as one of the 12 countries most at risk for climate-related problems. Though Bangladesh's contribution to global green house gas emissions is one of the lowest in the world, its low topography, disadvantageous geographic location, high density of population etc makes it more vulnerable to climate change (Islam, 2008). United Nations warned that[3]-

- A quarter of Bangladesh coastline could be inundated and about 17% of the land mass go under water, if the sea rises 3 feet in the next 50 years,
- Approximately 30 million people will be displaced from their homes, making them '*climate refugees'*.

[1] See http://ec.europa.eu/environment/index_en.htm

[2] According to IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*

[3] See http://www.thefinancialexpress-bd.com/2009/10/19/81946.html

Bangladesh is situated in the Ganges, the Brahmaputra and the Meghna (GBM) delta-the world's largest Delta. These three rivers also give Bangladesh one of the worlds most complex river systems (Khorshed, 2003). These three river systems drain to the Bay of Bengal through Bangladesh. This location increases the risk of flooding in Bangladesh.

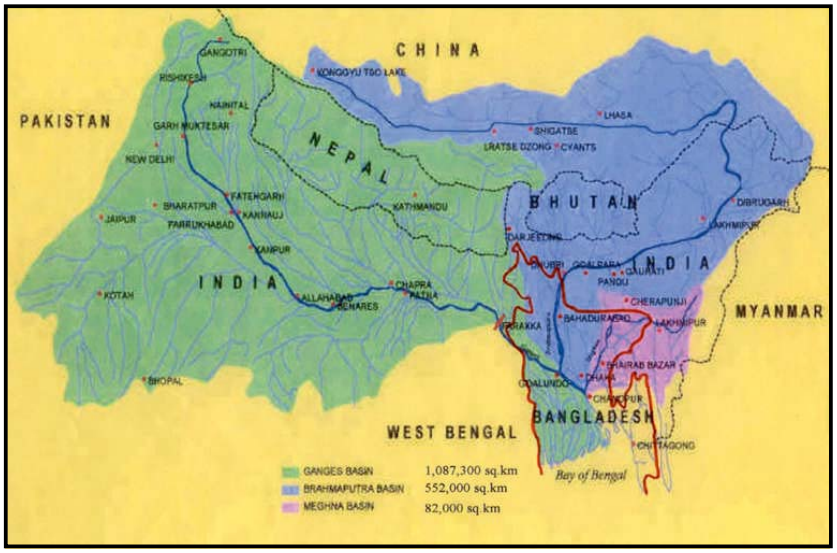


Figure 1.1: The Catchment areas of the GBM river system
Source: Hossain, 2007

The typology of floods induced by climate change in Bangladesh can be categorized into five groups: riverine, rainfall induced, flash, storm surge and storm water floods.[4]. Vulnerability to floods is aggravated by the high population density, extensive pressure on land, extreme poverty[5], illiteracy and traditionally agriculture dominated economy.

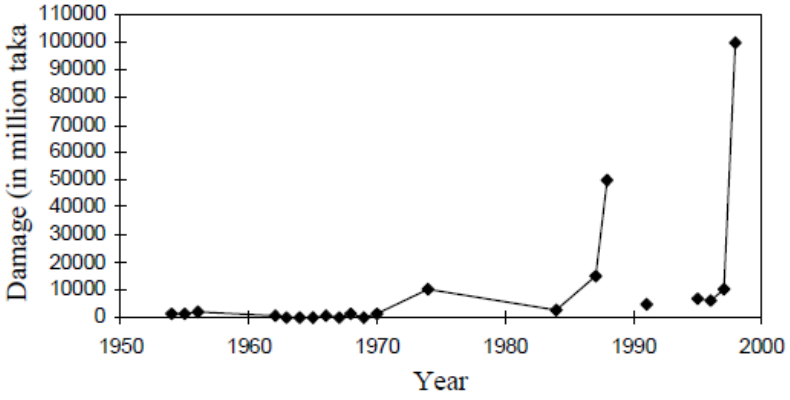


Figure 1.2: Flood damage in Bangladesh during 1955-1999
Source: Mirza et al. (2001)

[4] See Glossary
[5] According to World Bank estimate (2009), 40% population of Bangladesh live below the poverty line (people living on $1.25 per day).

1.2 Adaptation to climate change

'Adaptation is all about the quality of local knowledge and local capacity and willingness to act'. (Satterthwaite et al. 2007, p.51)

Adaptation measures to climate change are the actions or adjustments in the decision environments undertaken to reduce vulnerability to observed or projected climate variabilities (Adger et al. 2007). It can be categorized according to different dimensions and scales, for instance, levels like local, regional, national, typology of specific measure, actors, time scale etc. Planned adaptation measures to climate change are not commenced as stand alone measures, they are usually part of broader development goals.

Adaptation can have both planned and reactive actions, dealing with current climate variability and also with the future projections. The IPCC fourth assessment report states with very high confidence that adaptation to climate change is taking place but it is inadequate. Human being is considered to be the most adaptable of all species. In the history, it is evident that human being is adapting to climate variability. So, adaptation to climate is not a new phenomenon. But the issue of climate change has given this challenge a complex facet. Moreover, adaptive capacity varies even within the same society. There are several factors which influence capacity to adapt i.e. available resources, governance, institutional strength (Adger et al. 2007). Besides adaptive capacity, adaptation can be impeded by certain factors like intensity of climate variability and knowledge gap.

These adaptation measures are needed to be assessed. It is for basically three interlinked objectives, prioritizing, screening to ensure appropriate response and to evaluate the consequence and effectiveness of the measures. The most imperative thing is adaptation measures have to be mainstreamed into the relevant sectors to ensure sustainable development planning.

1.3 Vulnerability of Dhaka to climate change and flooding

Dhaka, the capital of Bangladesh is one of the world's largest megacities, which is subjected to high rate of urbanization. According to researchers, climate change poses risks to the Dhaka city in two ways: one is flooding and the other is heat wave. Behind flooding, the key climate driven variabilities are erratic and prolonged rainfall with the increase in precipitation and river flow changes caused by sea level change.

Dhaka is situated in the central area of the flat deltaic plain of the three large rivers, the Ganges, the Brahmaputra and the Meghna (Bala et al. 2009). Dhaka falls under the active river tidal zone. The low lying areas are often engulfed by the high tide influenced by the sea tide. It is assumed that the sea level will rise by one meter by 2050, it may even push the coastline within 60 to 100 km to the inlands of Dhaka (Alam et al. 2007)[6]. Flooding has become a regular event in Dhaka not only by the overflow of river but also through water clogging. The

[6] See annex 1

water depth goes up to 40-60 centimeters resulting infrastructure problems, economic loss, damages and more on.

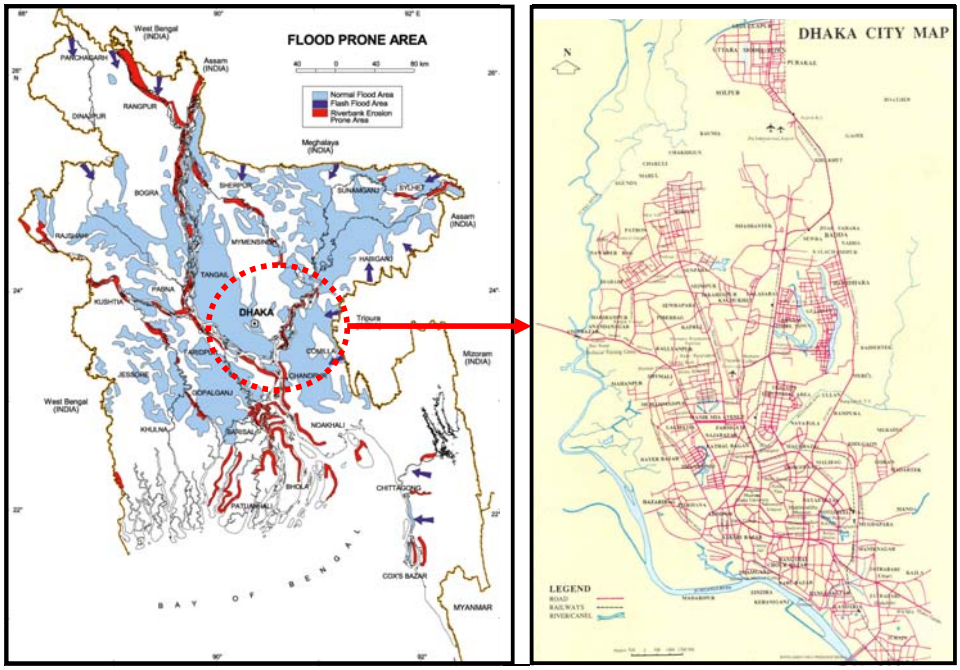


Figure 1.3: Flood prone areas of Bangladesh **Figure 1.4: Dhaka city (Blow up)**

Source: Adapted from the Geographical Information Systems Division of Bangladesh Centre for Advanced Studies (BCAS).

Dhaka has experienced several major floods since very early days which can include the most recent 1988, 1998, 2004, 2007 floods. The main reasons are the outflow of rivers, excessive rainfall and internal water logging. The 1998 flood was the most severe flood in recent history when almost eighty percent of the city was inundated. Even the protected areas are also inundated in some parts, one of the reasons behind it was the hydraulic leakage, failure in sluice gate operation. This event states that even the existing flood protection measures should also be reviewed.

Illegal encroachment of wetlands, drainage congestion, inadequacy of drainage system, dumping of wastes in the canals are accelerating the water clogging. The result is inundation of different parts of the city for many days leading towards economic, livelihood and environmental damage. There are some protective measures that government has planned but due to lack of compliance with policies, rules and regulations and the limitation of resources, implementation cannot take place properly.

L-R: Trouble in traffic movement, disruption of water supply
Source: L-R- ipsnews.net/pictures/Dhaka070908hr.jpg, The Daily Star, 2 November, 2007

1.4 Problem statement

The low lying area of Dhaka city, which is mainly the Eastern part, is at high risk. Basically the low lands and the water bodies act as the water retention areas which help to sustain the natural ecosystem as well. Traditionally, the water retention areas of Dhaka city have been efficiently storing the excess water caused by excessive rainfall and the khals (canals) connected to the rivers gradually drained the water to the rivers. As a result, there was no water clogging. But the scenario is changing. The population of Dhaka is increasing alarmingly and there is land scarcity, it is leading towards the encroachment of these water retention areas which mostly lies in the Eastern part of Dhaka city. And also the city drainage system has not improved with the pace of rapid growth of urbanization while most of the canals out of around 50 in the city have either been filled up entirely or partially over the last two decades, said experts. Consequently, these low lying areas suffer from inundation.

The Eastern area is the most vulnerable part of the Dhaka city to annual flooding. According to available literature the eastern part (nearly 119 square kilometers) of Dhaka was almost completely inundated in the floods that occurred in 1988, 1998 and 2004 and it was inundated for the longest period of time than the other parts of the city. It is not only affected by the external flood which is caused by the rise of river level, but also by the internal flood caused by the storm water and lack of drainage[7].

Under the Dhaka Integrated Flood Protection project the western part was protected by embankments and the drainage system was also improved before the 1998 flood. But during the 1998 flood, even some of the protected areas were inundated, this indicates the existing adaptive measures are needed to be improved as well. The Eastern part is still unprotected[8]. This increases the urgency of the need to adapt to current climate variability and future climate change and also creating the tools for assessing different adaptation measures.

[7] For detail problem tree, see Annex 2
[8] See Annex 3

1.5 Rationale of the study

'*Sustainable development can reduce vulnerability to climate change, and climate change could impede nations' abilities to achieve sustainable development pathways'*[9].

More than 70% population of Bangladesh is vulnerable to flooding (Mirza, 2003). And this number will increase along with the population increase since climate change impacts are projected to be exacerbated in the coming future. If there is lack of effective locally driven adaptation measures, it will cause serious adverse effects on the vulnerable groups and the national economy as well.

It is evident from the above stated problems that climate change and flooding is no more an environmental issue only, it is the vital of development as well. It has adverse impact on the MDG attainment, for instance, the extensive damages caused by flood impedes the goal of poverty alleviation and economic growth, the goal of gender equality is in danger since woman are among the most vulnerable groups to flooding and climate change, goal 4,5,6 targeting towards health is highly under threat because of the extensive water borne diseases due to flooding and goal 7 of environmental sustainability is struggling for survival since the major impact of climate change is on the environment itself. Hence, it is needed to understand the synergy between successful adaptation to climate change and successful local development (Satterthwaite et al. 2007).

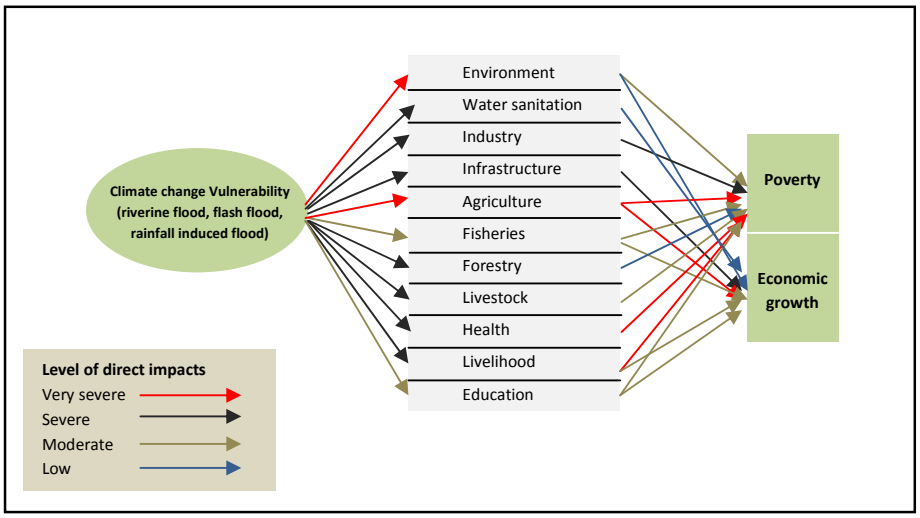


Figure 1.5: Probable Impacts of Climate Change on Poverty Reduction, MDGs Attainment and Economic Growth in Bangladesh
Source: Sarwar, 2009

Nevertheless undertaking adaptation measures without proper assessment may aggravate the adverse impacts or lead to wastage of limited available resources. Adaptation assessment is deemed necessary for ensuring efficiency since the level

[9]Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Summary for Policymakers, P.20.

of vulnerability is very high and resources are very limited, to avoid mal adaptation which may occur in the absence of effective adaptation assessment and last but not the least, for prioritizing the measures. Duplication of works and wastage of resources is a common phenomenon in Bangladesh in the climate change sector. Though vulnerability assessment is being carried out these days but adaptation assessment is still insignificantly appeared in the whole process of climate change adaptation. The development of an integrated framework to assess the adaptation policy options and measures is thus deemed necessary in this context.

Therefore, this research aims to provide an effective assessment for the adaptation measures (current and potential) to reduce the vulnerability of climate change. It will also formulate an analytical framework for the prioritization of government's most effective adaptive initiatives and measures that can be undertaken to address flood risk in the city.

The assessment framework will be applied and tested at the Eastern fringe of Dhaka city. Based on the assessment and analysis, potential adaptive measures will be identified for more effective action taking into account the existing limitations. Based on study's assessment framework and lessons from other case studies with similar context in other cities around the world conclusions will be drawn.

L-R: Water logging in Secondary road of Dhaka, water logging in main arterial road of Dhaka

Source: National Adaptation Program of Action (NAPA), Final Report, 2005

1.6 Research objectives

- Assess and prioritize the most effective adaptation measures to the risks of flooding for the Eastern fringe of Dhaka.
- Investigate the vulnerability of the Eastern fringe of Dhaka to flooding.

1.7 Research question

- What are the most effective adaptation measures against flooding for the Eastern fringe of Dhaka?

1.8 Research Sub questions

- Which are the most vulnerable types of capital assets in the Eastern fringe of Dhaka?
- What are the initiatives and measures taken by the Government to reduce the vulnerability of the Eastern fringe to flooding?
- Which are the main aspects and criteria to consider during the assessment of available adaptation options?

1.9 Thesis structure

Chapter 1: Introduction.

Chapter 1 provides an introduction of the climate change scenario globally and also in the context of Bangladesh. It builds up the need of adaptation to climate change by stating the vulnerability of the research area. This Chapter puts forward the problem statement and rationale of the study along with the research objectives and questions with an intention to provide an understanding of the focused topics that will be addressed in the research.

Chapter 2: Literature review

Chapter 2 puts down the theoretical foundations and concepts relevant to the research topic. This chapter also takes an attempt to find out the relationship between the relevant concepts and approaches. It analyzes the concepts with practical examples all around the world. Cases on climate change adaptation bearing relevant context of the developing countries all over the world have also been analyzed here. The lessons learnt from the cases will help to formulate the proposed adaptation options for the study area. At the end of the chapter, a potential outcome is received as a guideline for the research work.

Chapter 3: Research methodology

Chapter 3 basically contains research typology, research design, data collection and data analysis methodologies. This chapter formulates the framework for data collection and data analysis. It also states the analytical framework for the research.

Chapter 4: Overview of the study area

Chapter 4 provides a brief overview of the study area, i.e. context of the site, urbanization trend, climate, natural drainage system, eco system, land profile and land typology of the study area. Flood dynamics of Dhaka East is also explained here in terms of flood typology.

Chapter 5: Research findings and analysis

Chapter 5 encapsulates the findings of the research and analysis based on the research questions. Vulnerable sectors of the study area have been identified in this chapter. Initiatives undertaken by the Government to reduce the vulnerability of EFA have been figured out as well. This analysis has led to the prioritization of

adaptation options which is the main objective of the study. In the process, the criteria needed to be considered in the adaptation assessment are also identified and presented in this chapter.

Chapter 6: Conclusion

This last chapter of thesis presents the conclusive remarks for the whole study along with answering the research questions. Interpretation of the results and the contribution of the research are drawn as well. Lessons learnt from the study have been brought into light in this chapter along with stating the further scope of research.

Chapter 2: Literature Review

This chapter puts down the theoretical foundations and concepts related to the selected thesis topic. Figure 2.1 illustrates the areas of the study. It starts with the discussion of vulnerability which serves as the root of the research problem. The succeeding parts encapsulate principles of adaptation planning and approaches of planning. The chapter further settles upon the adaptation strategies applied by different bodies and tries to find out a relationship among them. This is followed by the prioritization process of the adaptation measures. This section analyzes different prioritization methodologies, intends to identify the relationships among them and appropriateness of certain method in specific situation. One method has been selected in response to the research context and scrutinized in relevance with specific case study. Relevant cases from developing countries of Africa and Asia have been analyzed bearing similar context. Potential lessons are drawn from the analysis that will assist to formulate feasible adaptation options to reduce vulnerability to flooding of the study area. The conceptual framework for the thesis is formulated in this chapter.

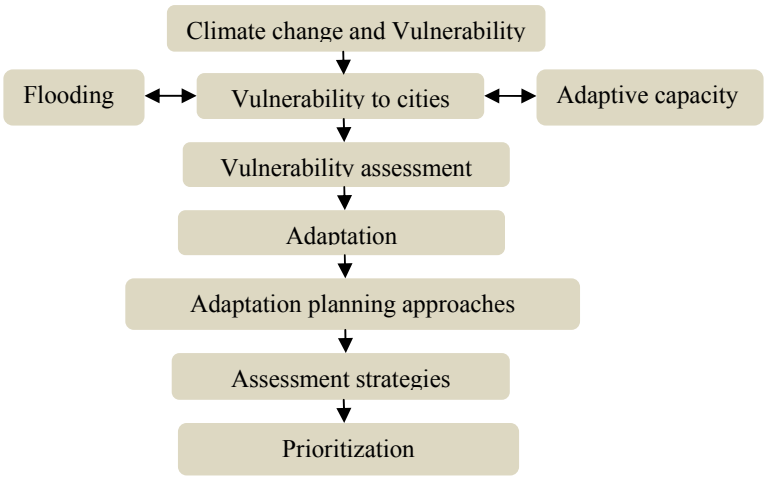


Figure 2.1: Literature review structure
Source: Author, 2010

2.1 Concept of vulnerability

In general term, the word 'Vulnerability' stands for the degree to which a system is prone to be affected due to the exposure to hazards (Turner II et al. 2003).According to United Nations (2004), hazard is defined as 'a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental disruption'. United Nations (2004) differentiate vulnerability aspects into four categories in relevance to disaster reduction, physical aspect which is defined by the exposure of vulnerable elements, economic aspects which stands for individual and communal economic resources of the region, social aspects which on the other hand describes the non economic factors that determine their welfare, and last but not the least, environmental aspect which reflects the environmental status of that region.

2.1.1 Vulnerability concept according to different approaches

2.1.1.1 Physical and social science approach

Physical science and social science defines vulnerability from two different but interrelated perspectives. Physical science defines vulnerability as the residual impact of climate change in absence of adaptation, this actually entails the external properties of the system. And according to social science, vulnerability is the state that exists within a system before it encounters a hazard climatic event (Kelly et al. 2000; Brooks et al. 2005). This stands for the internal properties of the system which depends on the context.

2.1.1.2 Integrated approach

Turner et al. (2003) states that these two concepts from social and physical science can be fused together to have a more integrated view of vulnerability. This integrated approach of vulnerability is reflected in the definition of vulnerability according to IPCC Third Assessment Report (McCarthy et al. 2001, Glossary), 'The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity'. Thus it possesses both internal and external dimensions. External dimension refers to the exposure and sensitivity to risks, and internal dimension is the coping capacity to a hazard.

Exposure refers to the exposure of a system to stimuli that act on that system, i.e. climate variability. ***Sensitivity*** stands for 'responsiveness of a system to climatic variability and the extent to which this responsiveness might be affected' (Gbetibuo et al. 2009). ***Adaptive capacity*** is the system's ability to cope with climate variability and climate extremes as well as to restrain probable damage. The framework of the IPCC fourth assessment report (AR4) states a vulnerable system to be exposed and very sensitive to climatic variability where sensitivity holds the probability of damaging effects and for which the adaptive capacity is severely constrained. Therefore, the relationship can be illustrated as follows:

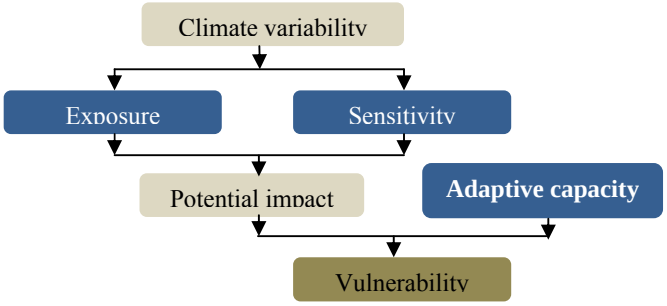


Figure 2.2: Relationship between vulnerability components
Source: Author (2010)

In this research, vulnerability is comprehended to be the possibility of people or system to be harmed in any ways by the direct or indirect impacts of climate change.

2.2 Understanding vulnerabilities of cities to climate change

According to Fourth Assessment of the Intergovernmental Panel on Climate Change (Adger et al. 2007, p.7):

"The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources, and those in areas prone to extreme weather events, especially where rapid urbanization is occurring".

"Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas. They tend to have more limited adaptive capacities, and are more dependent on climate-sensitive resources such as local water and food supplies.

"Where extreme weather events become more intense and/or more frequent, the economic and social costs of those events will increase, and these increases will be substantial in the areas most directly affected. Climate change impacts spread from directly impacted areas and sectors to other areas and sectors through extensive and complex linkages."

Table 2.1, adapted from the IIED Human Settlements Discussion Series on Adapting to Climate Change in Urban Areas, which is drawn from the Fourth Assessment of IPCC, listing manifold aspects of climate change, present and projected impacts, and the affected sectors or groups.

Table 2.1: Selected paradigms of impacts of climate change and the interrelation with other courses

Climate-driven phenomena	Evidence for current impact/ vulnerability	Other processes/ stresses	Projected future impact/ vulnerability	Zones, groups affected
a) **Changes in extremes**				
Tropical cyclones, storm surge	Flood and wind casualties & damages; economic loses; transport, tourism, infrastructure (e.g. energy, transport), insurance	*Land use/ population density in flood-prone areas; flood defenses; institutional capacities*	*Increased vulnerability in storm-prone coastal areas; possible effects on settlements, health, tourism, economic and transportation systems, buildings & infrastructures*	*Coastal areas, settlements, and activities; regions and populations with limited capacities and resources; fixed infrastructures; insurance sector*
Extreme rainfall, riverine floods	Erosion/landslides; land flooding; settlements; transportation systems; infrastructure	*Similar to coastal storms plus drainage Infrastructure*	*Similar to coastal storms plus drainage infrastructure*	Similar to *storms*

Climate-driven phenomena	Evidence for current impact/ vulnerability	Other processes/ stresses	Projected future impact/ vulnerability	Zones, groups affected
b) Changes in means				
Precipit-ation	Agricultural livelihoods, saline intrusion, tourism; water infrastructures, tourism, energy supplies	*Competition from other regions/ sectors; water-resource allocation*	*Depending on the region, vulnerabilities in some areas to effects of precipitation increases (e.g. flooding, but could be positive) and in some areas to decreases.* Water-resource challenges in affected areas; shifts in locations of population & economic activities; additional investments in water supply	Poor regions and populations
c)Abrupt climate change	Analyses of potentials	Demographic, economic, and technological changes; institutional developments	Possible significant effects on most places and populations in the world, at least for a limited time	Most zones and groups

Dark shading with italic text stands for very significant in some areas or sectors, a light shading represents significant and no shading stands for the significance is less evidently recognized.

Source: *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge and New York, pages 357-390.

The intensity, number of extreme weather events and climate variability defines the risks posed in the cities. For those, where these are frequent, are under high risk. But the risk varies by the housing and infrastructure conditions, preparedness mechanisms and basic emergency services. For this reason, the rich cities are less vulnerable. But there are exceptions as well, for example, the damages caused by Hurricane Katrina in 2005 in New Orleans, was basically caused by the lacking of the above mentioned mechanisms. This also exemplifies the vulnerability of the lower income groups.

Cities in the deltaic plain are described to be highly susceptible to climate change. An amalgamation of river, wave and tide processes form delta in course (Nicholls et al. 2007). The vulnerability of deltas posed by climate change is highly manipulated by human development patterns. Some of the familiar upshot of human activity are alteration of tidal flow patterns, flood control works etc. Deltas are specifically vulnerable due to the sea level rise, which in turn poses the highest risks for the vastly populated cities in the deltaic plains. Box 1shows the

vulnerability of deltaic plains in the whole world and reaches a conclusion with the special focus on the vulnerability of the highly populated Asian deltas.

Box 2.1 Deltas: High Vulnerability

According to the estimation of Ericson et al. (2006) approximately 300 million inhabitants stays in 40 deltas all over the world. The average density of population is 500 people/sq. km with the major population in the Ganges- Brahmaputra Delta which is significant with growing urban areas (Nichols et al. 2007). Ericson et al. (2006) estimates that more than one million people will be directly affected by 2050, one of these three deltas is the Ganges- Brahmaputra delta in Bangladesh. 75% of the estimated affected population is from the Asian deltas, which is projected to be exacerbated by the climate variability and increasing human pressure. These Asian mega deltas are posed to intensive land use and to the growth of mega cities. Many cities of these deltas are subjected to flooding due to river floods and also storm surges.

Figure: Relative vulnerability of deltas as shown by the indicative population potentially displaced by current sea level trends on 2050 (Extreme = >1million, high=1 million, Medium = 50,00 to 5,000, following Ericson et al. 2006.
Source: *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, Coastal systems and low-lying areas.

2.3 Climate change and flooding: threat and responses to cities

Flooding is a term which includes a wide range of events, comprising of overflow of rivers by extensive rainfall, storm surge, glacier melt, sea level rise, rain water accumulation in low lying areas due to lack of drainage and higher water level and water intrusion on to land because of cyclone surges (Handmer et al. 1999).

According to IPCC working group II, 'Many millions more people are projected to be flooded every year due to sea level rise by the 2080s. Those densely-populated and low lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk. The numbers affected will be largest in the mega deltas of Asia and Africa while small islands are especially vulnerable.'[10]

[10] Adger et al. 2007, op, cit., page 7

Urban areas are always under some risk when there is prolonged rainfall. The paved surface also resists rainwater to penetrate and the result is more runoff which can easily exceed the capacity of the drainage system. In well governed cities the situation is better, while in poorly governed cities, this is a frequent event. Climate change poses risk to cities mainly in three ways, one is from the sea- by sea level rise and storm surges, the other is by heavy and prolonged rainfall and also from changes that increase river flows- which may be caused by the increase glacial melt (Satterthwaite et al. 2007). According to IPCC working group II, this heavy precipitation will remain to be increasing, posing flood risks to the cities (Nicholls et al. 2007). In many countries the average rainfall may decrease due to climate change, but the greater extremes of individual rainfall will not let the overall flooding risk to be reduced.

Box 2.2 Flooding in African and Asian cities

The problem of frequent flooding is increasing in the African cities posing severe risks. This scenario is aggravated by climate change by changing the rainfall patterns and increasing the frequencies of storm surges (Satterthwaite et al. 2007). In many of these cities, flood risks are higher because of the lack drainage for the surface runoff, since through the paved surface water cannot penetrate, inadequacy of the drainage system and obstruction of the natural channels. The risk is being aggravated by the informal settlements in the floodplain areas.

In these areas, basically four types of flooding occurs: localized flooding caused by inadequate drainage, flooding from the rivers on which banks cities are built, flooding from streams whose catchment area is within the built up area and last but not the least coastal flooding (Satterthwaite et al. 2007).For example, in Mombasa, it is estimated that 17% will be submerged with a sea level rise of .3 meters (Awuor et al. 2007). More on that, a huge area considered to be inhabitable and also not fit for agriculture as well due to soil intrusion and water logging. This city has a history of flooding posing serious damage almost every year.

Within Asia, for instance, in India, one of the severe climate change risk is the riverine and inland flooding. The situation is aggravated by the increased precipitation and higher peak monsoon river flows posing risks to the population (Satterthwaite et al. 2007). The primary reason behind this scenario is the high density of population, which is combined with poor infrastructure, high poverty, complex land and water tenure regimes (Vries et al. 2007).

2.4 Relationship between vulnerability and adaptive Capacity

There are different parameters which can contribute to the adaptive capacity of a system, group or individual, these are economic resources, access to technology, access to information, institutional assistance and equitable distribution of resources (Pelling, 1999). Generally adaptive capacity is proportionately related to the level of development. It has been stated after conducting research on vulnerability and adaptive capacity that there are some general indicators, i.e. education, health and income, and the others are dependent on specific climate change impacts i.e. relevant institutions, knowledge and technology (Brooks et al. 2005; Downing, 2003; Tol et al. 2007). IPCC Third Assessment Report states that social factors like human capital and governance structures also influence adaptive

capacity. According to Pelling (1999), vulnerability is constituted with three components: exposure, resilience and resistance[11]. For instance, if flood water intrusion is considered to be the exposure, then human adaptive capacity to lessen the adverse effect are the resilience and resistance (Few, 2003).

2.5 Vulnerability Assessment

Vulnerability assessment refers to the process of identifying and quantifying the vulnerability of a system. It is a major feature for fastening climate change impacts to development planning. Over the past several decades, methods of vulnerability assessment have been developing. According to Downing et al. 2002, the probable outputs from vulnerability assessment are:

- An analysis of current vulnerability which includes the representative vulnerable groups.
- Narrating potential future vulnerabilities in connection with the present vulnerabilities.
- Comparing vulnerability under diversified socio economic conditions, climate variabilities and adaptation responses.

The ultimate job is to relate these outputs to stakeholder decision making, public awareness and further assessments (Downing et al. 2002).Vulnerability assessment can reduce the uncertainties of long range investment decisions. Another important benefit is the promotion of stakeholder dialogue.

Three primary models can be identified for conceptualizing and assessing vulnerability. One is the Risk- hazard framework, which forms the base for risk and disaster management. It interprets vulnerability as the dose- response relationship between an external hazard to a system and its impacts (Fussel et al. 2006). This view can be interlinked with the sensitivity concept in IPCC terminology. The social constructivist framework predominates in political economy and human geography. In this framework, vulnerability is stated as a preceding condition of a household or community which is established by socio-economic and political factors (Fussel et al. 2006). Relevant studies suggest a casual framework that focuses on different abilities of communities to cope with external stresses. According the integrated approach of vulnerability[12], the whole process of vulnerability assessment constitutes with the sensitivity, exposure and adaptive capacity analysis. The impacts of the climate variabilities are needed to be identified for the sensitivity analysis. The whole process is illustrated in the figure 2.3.

[11] *Resistance is the amount of change a system can undergo without changing state.* (IPCC, TAR, 2001)
[12] See 2.1.1.2

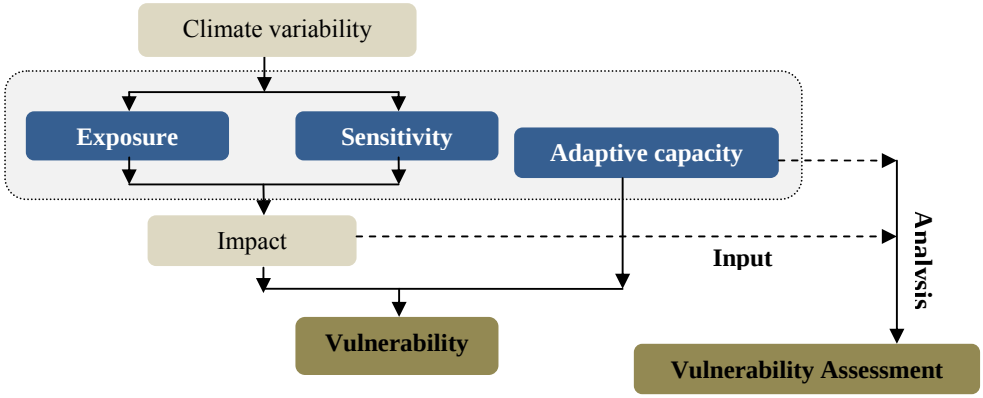


Figure 2.3: Vulnerability assessment framework in relation with vulnerability components
Source: Author, 2010

2.6 Adaptation: Process and taxonomy

Human being is considered to be the most adaptable of species. In the history, there are evidences of human being adapting to climate variability, sometimes by altering lifestyle or by adjusting settlement or sometimes by altering food protection system and so on. So, adaptation to climate is not a new phenomenon. But the issue of climate change has given this challenge a complex facet. Adaptation to climate change can be defined as any action undertaken to lessen the vulnerability of a system, population or individual to the unfavorable effects of climate change. Both pre and post disaster vulnerabilities should be addressed by the adaptation strategies i.e. the focus should be on reducing the hazard and peoples' exposure to the hazards, and also reducing the impact of hazards has to be noticed as well. This is pre disaster response. While post disaster can be reducing the probable impacts of future hazards. Adaptation can contribute to the reduction of adverse effects of climate change but it cannot diminish it completely. Every adaptation to climate change which is done in a systematic way should comprise of three basic components: adaptation to what, who or what adapts, and how does adaptation occur (Figure 2.4).

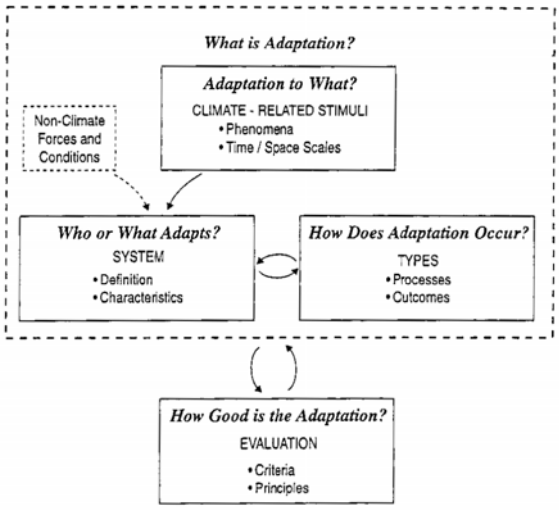


Figure 2.4: Adaptation to Climate Change
Source: Smit, et al. 1999

When and how does adaptation occur?

Adaptation needs usually come up from climate conditions i.e. climate variability and extreme. Both natural and anthropogenic climate change has to be considered in adaptation, since risk is generated from both (Fussel, 2007).There is a tendency of unclear differentiation between the anticipatory and reactive adaptation. Exact and correct information about the future trend can reduce the loss and cost of adaptation. To answer the question 'how does adaptation occur?' both the process of adaptation and forms of adaptation has to be taken into account (Figure 2.4). The taxonomy is diversified; many typologies have been identified according to different attributes.

Table 2.2: Bases for differentiating adaptations

General differentiating Concept or Attribute	**Examples of Terms Used**	
Purposefulness	autonomous spontaneous automatic natural passive	planned purposeful intentional policy active strategic
Timing	anticipatory proactive *ex ante*	responsive reactive *ex post*
Temporal Scope	short term tactical instantaneous contingency routine	long term strategic cumulative
Spatial Scope	localized	widespread
Function/Effects	retreat - accommodate - protect prevent - tolerate - spread - change - restore	
Form	structural - legal - institutional - regulatory - financial – technological	
Performance	cost - effectiveness - efficiency - implementability – equity	

Source: Smit et al., 1*999*

Most of the attributes can be described which can differentiate between different forms of adaptation. These typologies are dependent on the system (who or what adapts?) and climate related stimuli (adaptation to what?) (Smit *et al*. 1999). For instance, adaptations in the informal settlements towards flooding is an autonomous and reactive one, whereas the adaptation commenced by governmental institutions is usually a planned and sometimes anticipatory (Smit *et al.* 1999).

Based on the timing, goal and motive of their implementation, the types of adaptation can be distinguished as follows:

Reactive and proactive adaptation: Adaptation is said to be of reactive or proactive depending on the approach. If the adaptation is in response to the

climatic adverse effects, then it is reactive. And if it is based on anticipation of future climatic events then it is proactive. In reactive (anticipatory) adaptation, since the impact has been experienced before, the resource allocation is easier, but in case of proactive one, the exact investment is hard to determine.

No regret, short term, long term adaptation: Reactive or anticipatory adaptation can be again categorized as no regret, short term and long term adaptation. 'No regret' actions are those actions by which society would benefit even if anthropogenic climate change did not take place (McCarthy et al. 2001). The short and long term are only differed by the time frame and extensiveness of the measure. For example, provision of accurate early weather warning warnings of hazards is a short term adaptation. Retrofitting technologies for the most critical zones is the medium term adaptation. On the other hand, relocation of the risk structures is the long term one (Heather et al. 2004).

Autonomous adaptation: Autonomous adaptation occurs without any predetermined or specific planning.

Mal adaptation: The concept of mal adaptation states the actions that tend to increase the impacts of climate change rather than reducing, which can also cause transferring of vulnerability from one to another, creating risks for the future generation is also a part of this (Satterthwaite et al. 2007). While preparing adaptation strategies, the removal of mal adaptation should be the first step.

2.7 Adaptation planning approaches

Diversified context of adaptation confirms that there is no single approach for adaptation planning. It can apply different methods to construct knowledge to specific assessment (Fussel, 2007).There are several approaches regarding the ways to deal with the impacts of climate change with a purpose of reaching a successful adaptation. The basic approaches can be summed up into three major ones: standard (IPCC) approach, risk approach and human development approach.

2.7.1 Standard (IPCC) approach

This approach was initiated by IPCC which was one of the earliest of all, hence it is considered as standard approach. At the first stage, this approach was based on climatic scenario[13] only whereas a socio economic scenario was incorporated into it at a later stage (Suraje et al. 2004).According to this approach based on climate scenario, impacts are being assessed and adaptation strategies are being developed. Since this approach is based on climatic scenario, it is more focused towards the future rather than the present vulnerabilities and impacts.

2.7.2 Risk approach

Risk assessment can be widely defined as the process of identifying, evaluating, selecting and implementing the actions with a vision of reducing the risk (Suraje

[13] 'Climate scenarios are plausible representations of the future that are consistent with assumptions about future emissions of greenhouse gases and other pollutants and with our understanding of the effect of increased atmospheric concentrations of these gases on global climate'-IPCC definition (http://www.ipcc-data.org/ddc_climscen.html)

et al. 2004).The core issue of risk assessment is the management of uncertainties leading to risk. It is not being long since the risk assessment is being applied in the field of climate change. The key reason behind this inclusion is the uncertainty in the climate change projection and the risk associated with this uncertainty. It is not feasible enough to work with probabilities while dealing with development goals (Dessai et al. 2004). In this approach, vulnerable units to climate change are identified by the relevant stakeholders. Jones (2001) proposed a seven step climate impact risk assessment, which is based on a simple concept but difficulty arise with the complexity of climate change. According to Suraje et al. 2004, the steps are as follows:

1. Identifying the key climatic variables affecting the exposure units being assessed
2. Creating scenarios and/or projected ranges for key climatic variables
3. Analyzing sensitivity to assess the relationship between climate change and impacts
4. Identifying the impact thresholds to be analyzed for risk with stakeholders
5. Risk analyzing
6. Evaluating risk and identifying feedbacks likely to result in autonomous adaptations
7. Consulting stakeholders, analyzing proposed adaptations and recommendation of planned adaptation options

Similar to the standard approach, this approach also somewhat relies on climate scenario (Step 2). Stakeholders' role is very critical in this approach since they define the impact thresholds (Step4). Another similar framework which follows this risk approach is commenced by the United Kingdom's Climate Impact Program. This comprises of eight stages:

1. Identifying problems and objectives
2. Establishing decision-making criteria, receptors, exposure units and risk assessment endpoints
3. Assessing risk
4. Identifying options
5. Appraising
6. Selecting
7. Implementing
8. Monitoring, evaluation and reviewing

Stage one is more based on risk screening, while stage two is basically qualitative risk assessment and stage three is risk assessment on the basis of a specific quantification.

2.7.3 Human development approach

Previously there was a misconception that climate change is only an environmental problem. But now it has been equally recognized as a development problem as well. Burton and van Aalst (1999) took the initiative to investigate climate change from a development perspective in order to look at the way through which World Bank can incorporate climate change vulnerability and adaptation into its job. At first, they examined present climate change adaptation practices to combat existing climatic variability. Their vision was to tackle the

future, present practices have to be developed. Climate scenario has no role in this framework. The focal point of this approach is on the level of exposure to existing climatic variability and the determinants of adaptive capacity, i.e. access to information, financial resources, technological ability, social and institutional arrangements.

2.8 Adaptation assessment methods

Adaptation assessment refers to the identification of options to adapt to climate change, it also includes their evaluation on the basis of some criteria, for example, costs, benefits, feasibility, availability (IPCC TAR, 2001 a). Though it seems to be clear on paper, but it is not in practice, since there is no common set of criteria or parameters to assess adaptation options in different locations and situations. Situation varies from case to case.

IPCC sets one of the earliest guidelines for adaptation assessment. It is not been very early when United Nations Development Program and the secretariat of the UNFCCC have also come up with two different types of guidelines. Methodologically these three approaches hold quite similar framework for assessing adaptation strategies.

2.8.1 IPCC guidelines for impacts and adaptation assessment: First generation framework

The guidelines for impacts and adaptation assessment provided by IPCC consist of seven steps (Figure 2.5).

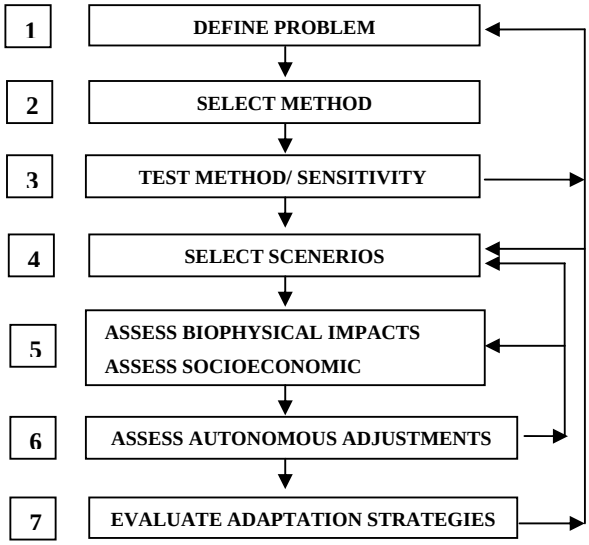


Figure 2.5: The seven steps of climate impact assessment

Source: Carter et al. 1994

It is vivid from the design of the stages that it does not consider vulnerability of a sector or system, rather it is impact driven. But diagnosis of vulnerability should be of prime focus while assessing adaptation options for developing countries. The reason behind it is, disaster is the outcome of one or more hazards and some affected vulnerable elements (Mirza, 2003). Moreover, in the last two stages it is being assumed that responses of the adaptation are known, which always may not

be the case. Step 4 shows that relying on climate change scenarios, this approach is directed towards the future impacts rather than present impacts and vulnerability. Another major lacking in this procedure is the stakeholder participation. A successful adaptation needs the involvement and feedback of relevant stakeholders in every possible step.

2.8.2 UNDP adaptation policy framework: Second generation framework

UNDP (2001) came up with an adaptation policy framework which consists of five steps (Figure 2.6). It takes into account both present climatic variability and future climate change. The first generation framework was more focused on climate scenario. But this framework is basically based on climate science. This framework goes one step further than the first generation framework by including impacts to risk based assessments.

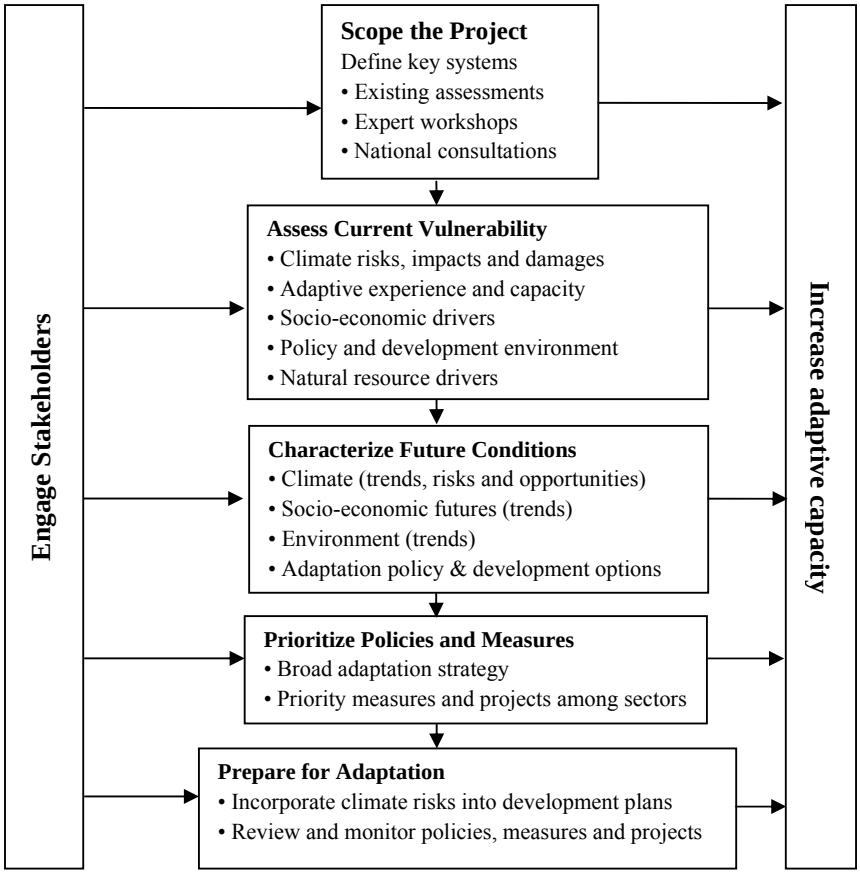


Figure 2.6: The adaptation policy framework or "second generation" framework
Source: UNDP, 2001

APF establishes a link between climate change adaptation and sustainable development and global environmental issues[14]. It addresses short term climate variability which will in turn reduce the vulnerability for the longer term. ''The essential starting point is the present'' (Burton et al. 2002, p.154). It gives equal importance to the strategies and the implementation process. APF is a mixed

[14] See http://www.undp.org/climatechange/adapt/apf.html

approach, since it builds upon standard approach, it resembles to risk based approach in stage three and steps two, four and five corresponds to human development approach.

However, it possesses some limitations. Though it requires inputs from the stakeholders, an element that was absent in the first generation framework, it is one way feedback mechanism. It does not reveal how the advantages of the implementation of the strategies will be distributed among the stakeholders. Another drawback is that the stakeholders are assumed to be known beforehand and therefore it does not show how to spot them. Each stage is dependant on various data, whereas the task to acquire data in developing countries is not an easy job.

2.8.3 UNFCCC's National adaptation programs of action (NAPA)

A major move by the UNFCCC was to facilitate the least developed countries to spot out their urgent priorities for adaptation options by means of the National Adaptation Programs of Action (NAPA).The priority adaptation options are those, whose further delay may lead to increased cost and vulnerability (UNFCCC, 2006).

"The UNFCCC provides the basis for concerted international action to mitigate climate change and to adapt to its impacts. Its provisions are far-sighted, innovative and firmly embedded in the concept of sustainable development" (UNFCCC, 2006).

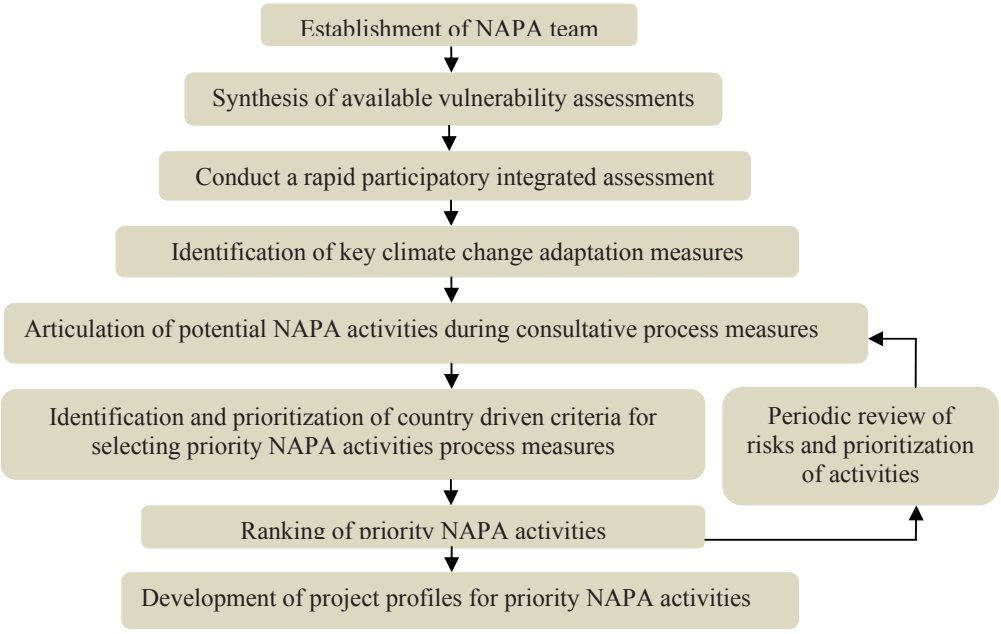


Figure 2.7: Flowchart of main steps in developing a NAPA
Source: Annotated guidelines for the preparation of National Adaptation Programs of Action, 2002

It has commenced a different approach for adaptation assessment in the LDCs. NAPA is a participatory action oriented adaptation framework which is country specific. It comprises of a set of guidelines addressing the immediate needs for the LDCs to adapt to climate change (UNFCCC, 2002).It addresses the low adaptive capacity of the LDCs and plan actions for adaptation according to that. Prioritization of adaptation activities is done according to country specific set of criteria, i.e. livelihood, health, food security, agriculture, socio economic factors, environmental amenities etc. This framework is based in current knowledge. But it tends to avoid the process of typical vulnerability and adaptation assessment.

The effective part of the framework of NAPA is that it builds upon the existing coping strategies at the grass root level to assess future vulnerability and adaptation responses. It does not rely on the climate scenario model. The assessment process includes two most vital parts, one is stakeholders involvement from all levels and the inclusion of the existing coping strategies.

2.9 Prioritization of adaptation measures

2.9.1 Correlation between different prioritization methods

There are several techniques applied for the prioritization o adaptation options. The three most applied techniques are: Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA) and Multi-Criteria Analysis (MCA).

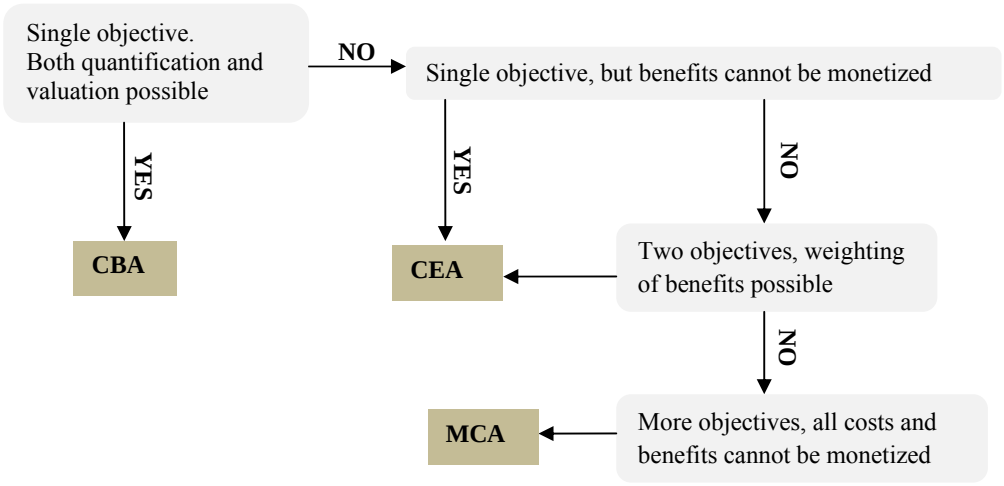


Figure 2.8: What method to use?
Source: Adjusted by Author, 2010

Different methods are applicable in different cases.CBA is specified to handle optimization, it gives a clear measure without ranking, whether or not to go for the implementation of specific measure. But it has to be expressed in monetary terms since main purpose of it is economic efficiency[15].The common factor allows

[15] See http://www.napa-pana.org/files/workshops/ethopia/Selection_prioritisation_HBosch.pdf

comparison and optimization of measures. In contrast, MCA can evaluate those measures which cannot be quantified. CEA lies in between the two above mentioned methods. It aims to cost different options that achieve the same goal**.** Similar to MCA, this method can also handle cases with multiple criteria provided these goals or objectives are possible to weigh against each other (See footnote 14).

2.9.2 Multi Criteria Analysis (MCA)

"A multi-criteria analysis describes any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives" (Brooks et al. 2009, p 46). To perform MCA method, objectives and related indicators have to be identified. These indicators can be both qualitative and quantitative. This method is appropriate for a participatory process since it employs stakeholders' participation in weighing the criteria (Brooks et al. 2009). Multi Criteria Analysis is a widely applied approach in relation to environmental issues, including climate change. In this process a measures are analyzed from different perspectives to formulate the output. It helps to categorize measures according to priority, for example, 'short term, small scale, highest priority', 'short term, large scale, highest priority', ' Long term, small scale, highest priority' etc. The key part of this method is the scoring, which can incorporate monetary or non monetary data, qualitative data like ++, +, -- and diverse rating scales. But for the purpose of comparing, these scales have to be standardized.

This process basically constitutes of three steps. First step is defining the criteria to be used for assessment of the adaptive measures. The next step is scoring and weighting. The measures are assessed on the basis of the stated criteria (scoring), how well they perform. And then the criteria are weighted using various techniques. And after scoring and weighting, the decisions are being analyzed with all uncertainties and the range of perspectives applying to the decision (TNA Handbook, 2009).

There are examples of successful application of MCA method all over the world; urban flood risk assessment in Germany (Kubal et al.2009), ranking of adaptation options for climate change for the Netherlands (Bruin et al. 2009), decision making process for policy planning in Canada (Qin et al. 2008) and more on.

Box 2.3 Prioritization of adaptation measures, NAPA

The preparation of NAPA is a participatory process involving stakeholders from all levels. In their prioritization process for the adaptation measures, they assume the following (UNFCCC, 2002):

- Relevant criteria and indicator is to be considered in the process
- Climate change cannot be always evaluated in monetary terms
- Most often, there is not enough data for conducting CBA or CEA
- In this process, participation of local people is necessary
- Suitable adaptation response is that which is clear and accessible for stakeholders' participation in order to make decisions.

To justify these principles, UN promotes MCA for the prioritization of adaptation measures for the least developed countries. It does not advocate for the traditional risk management tools because of the diversified risk uncertainty. After the vulnerability and hazard assessment, MCA is carried out for ranking options, since it is suitable when there are many relevant criteria in the decision making process and it is difficult to value because of uncertainty and it is needed to have subjective judgment. A site specific set of criteria for prioritizing adaptation options and a list of sectors are inspected within the NAPA process. These locally driven criteria should comprise of the degree of adverse effects of climate change, poverty reduction to improve adaptive capacity, cost effectiveness and it should be in line with the environmental agreements. These criteria are then applied to the sectors, for example, health, water, food, infrastructure, biodiversity, environmental amenities.

Source: *Prioritizing climate change risk and actions on adaptation*, Available on http://www.policyresearch.gc.ca/page.asp?pagenm=2009-0007_04, Last modified: April 20, 2009

2.9.3 Limitations of MCA

- There is a risk of overlapping or interdependency (Brooks et al. 2009). It does not allow complete independence of criteria.
- In this method, selection of criteria is not always straightforward, only those are selected which can be easily attributed. For instance, the criterion, biodiversity is difficult to attribute effect. In this case, expert judgment is taken to characterize the effect.
- If there are many options, i.e. more than eight, it is difficult to quantify the impacts and in this case, there is a risk of different MCA technique coming up with incomparable outcomes.

2.10 Cases on climate change adaptation options

2.10.1 Flood adaptation measures: A case for Dhaka East

As mentioned in the introductory chapter, being low lying area, Dhaka East is highly prone to flooding. Each year significant damages occur in this area due to flood hazard. High rate of urbanization and encroachment of wetlands are further aggravating the risk of flooding. After the catastrophic flood of 1988, Government of Bangladesh decided upon to protect Dhaka East. A set of measures including

both structural and non structural measures have been proposed to protect the area adapting a hundred year standard protection.

As per the Halcrow report (2006), this is planned to accrue through (a) physical protection of the assets from floods and drainage congestion, (b) lessening of frequent flood losses to productive enterprises, including the industrial units located in the area, (c) creating opportunities fro improving the present backland productive initiatives, (d) creating employment opportunities in semi urban and urban service sectors, (e) time and cost savings for vehicle operations, (f) safety from diseases due to pollution of water, (g) opening access of public and private entities to modern amenities of life and newer livelihood opportunities etc. The proposed measures are construction of flood embankment, pumping stations, regulators/ sluices, flood walls, construction and upgrading road network, protection of retention basins and canal improvement.

The aim of these proposed measures are to protect Dhaka East from both internal and external flooding. In depth social impact assessment, environmental impact assessment and economic & financial analysis has been conducted to confirm the feasibility of the proposed measures. Though it has been proposed long back, still the measures are not being executed.

2.10.2 Flood hazard management: A case of early warning system in Jamaica[16]

Jamiaca is prone to flash flooding which usually causes more devastation than the other categories of flood since adequate lead time is not there to have mitigative response. The frequency of disastrous flood in Jamaica is once in every four years. Therefore there is a need for undertaking adaptation measures to reduce the damages caused by flood. Flood warning systems are potential solutions since the cost is less and these can enhance the operations for other adaptation options.

The goal of the early warning system in Jamaica is to shield life and property by giving appropriate warning in time so that people can have time for preparedness. The Office of Disaster Preparedness and Emergency Management (ODPEM) acts as a collaborator in this system.

There are two categories of Flood warning system in practice in Jamaica-

I. **A Community Operated Flood Warning System:** This system is based on five basic elements: prediction of weather, detection of flood levels and rainfall level, communication, decision making and mobilizing i.e. evacuation of community. Jamaica holds three community flood warning systems established between 1991 an 1999.

II. **An Automatic (Real Time) Flood Warning System:** This system contains a set of rainfall and water level measuring stations set up key

[16] The case is taken from 'Flood hazard management, mapping and early warning system in Jamaica' written by Errol Douglas,2003 , accessible at *www.unisdr.org/ppew/info-**resources**/ewc2/.../**Errol_Douglas**.doc*

points in a watershed or its sub-basins. Each station is meant to transmit information in real time to the repeater stations. Repeater stations are again interlinked to a master station which accumulates all data and process. The changes in different places can be viewed in the master stations. ODPEM acts for the warning if there is any probability of flood occurrence and necessary actions are taken.

There are number of institutions which has vital role behind the successful flood warning system, these are ODPEM, National Meteorological Service, Water Resources Authority (WRA) and Community Flood Response Teams.

2.10.2.1 Success of the early warning system in Jamaica

- Warning in time for evacuation
- Saving of lives and property
- Effective reduction of flood damages with low capital and operational cost
- Constructive changes in solid waste disposal and land use pattern
- Overcoming of political barriers
- Communal initiatives
- Inter relationship between communities, public and private sector
- Other projects launch which supports flood disaster mitigation

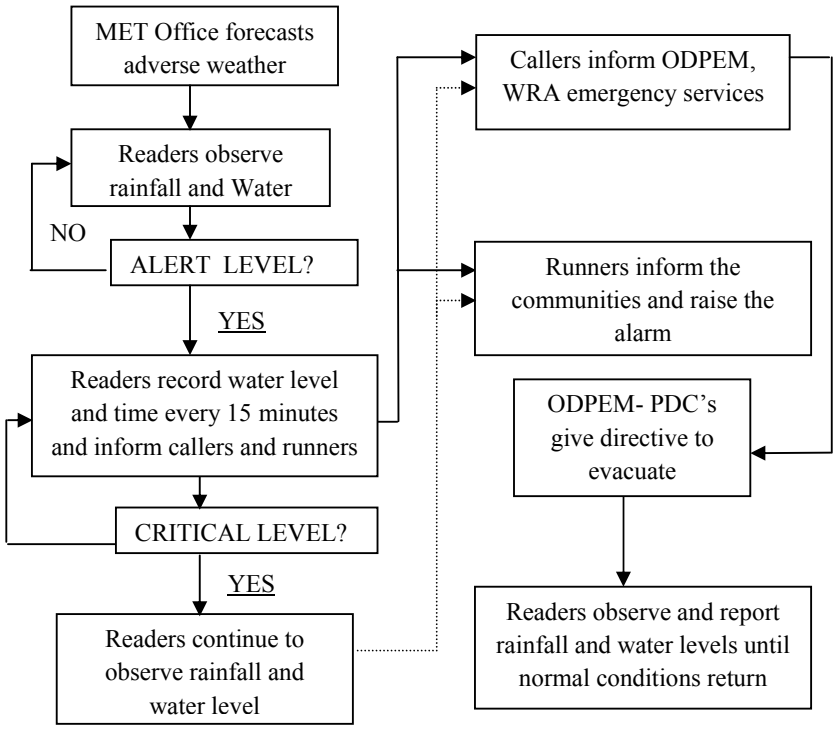


Figure 2.9: Flow chart showing how the early warning system of Jamaica works
Source: Douglas, 2003

2.10.2.2 Lessons learnt from the case of early warning system of Jamaica

Developing countries have limited capacity and resources to adapt to climatic hazards. Therefore, while selecting adaptation options for developing countries, this has to be kept in mind. This case states a vivid example how developing countries can successfully adapt to climatic hazards by reducing the amount of damage. It shows early warning system as an adaptation option which costs low capital and operational cost. But at the same time it can provide with warning on time so that the communities can get prepared and thus saving life and property. In this case, the system is more strengthen by community involvement.

Another trouble faced while implementing flood hazard management is lack of co ordination between different institutions. This case shows how organized and structured system can lead to a successful outcome. It also states the both options of warning system, at community level and also centrally. A combination of these two mechanisms gives a complete coverage of early warning system for the country.

In a word, this case states a vivid example of successful low cost flood hazard management with an organized and structured institutional arrangement and community involvement.

2.10.3 Enhancing emergency preparedness mechanism through GIS: A case of Allahabad city, India[17]

The emergency preparedness and response mechanism is predominantly concerned with the interaction between human and immediate environment under conditions which are predicted to be hazardous for life and habitat.

This case of Allahabad city, India states an innovative and effective example of emergency preparedness mechanism based on Geographic Information Systems (GIS). According to the National Aeronautics and Space Administration (NASA), GIS is a computer based system which is capable of assembling, storing, manipulating and displaying geographically referenced information. This technology can be used to map the vulnerability of an area to climatic hazards as well, by formulating hazard indices using the integrated geo-data base of all the relevant indicators (socio economic, hydrological, meteorological, agricultural etc).The case, Allahabad city, is surrounded by Ganges and Yamuna rivers and prone to frequent flooding. The primary reasons behind flooding are the overflow of the river because of water release of Meja dam and also due to heavy rainfall.

To analyze the overall risk, maps of the flood prone areas were produced using GIS system bearing the information of relief facilities like location of hospitals, road network and route of relief map.

[17] See http://www.gisdevelopment.net/application/natural_hazards/floods/ma08_217.htm

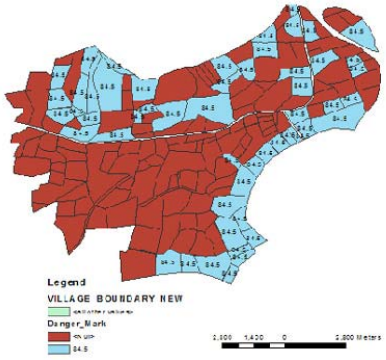


Figure 2.10: Map showing flood affected areas of the case

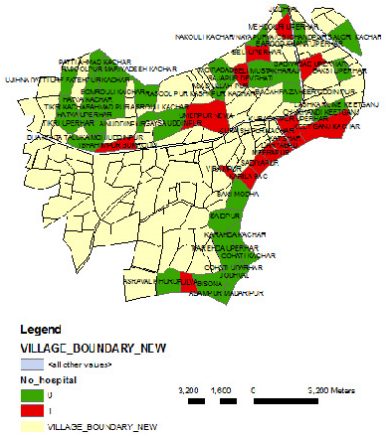


Figure 2.11: Map showing hospital facility in flood affected areas

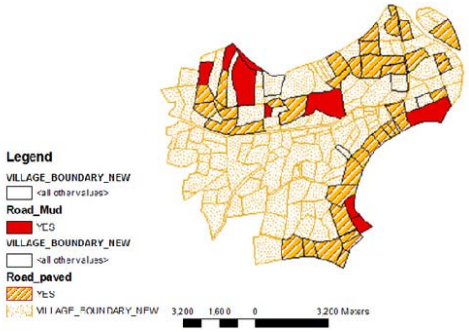


Figure 2.12: Map showing paved and mud road connectivity

Figure 2.13: Route of relief camp

Source: http://www.gisdevelopment.net/application/natural_hazards/floods/ma08_217.htm

The result shows that there are 54 villages surrounded by river which are under risk when river level goes up to 84.5 meters. These GIS maps help to decide the supply of food, water, location of camps and relief shelters in the safe areas.

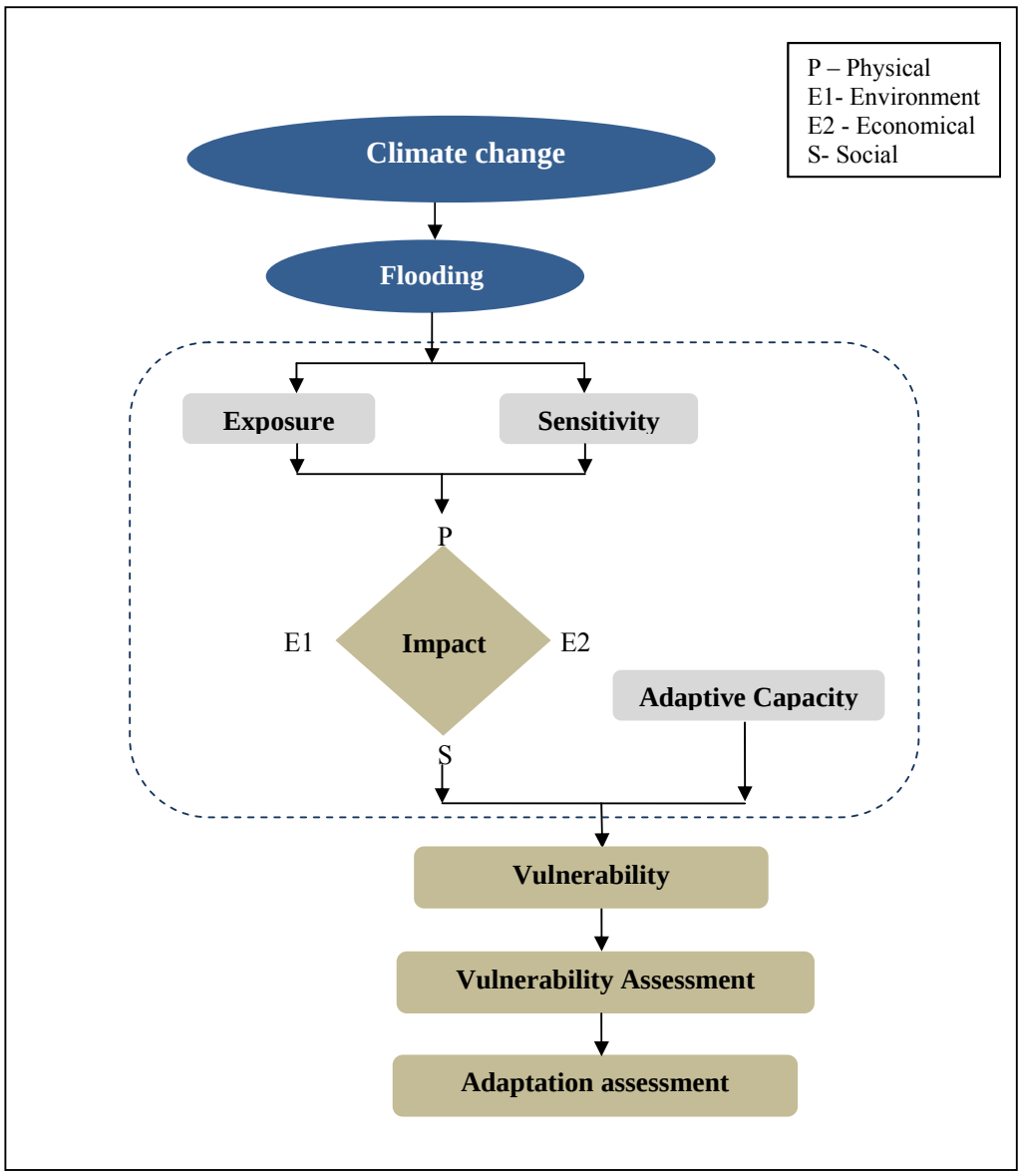
There are several success stories from the developed world also, showing efficient emergency response system to climatic hazard by using the GIS tools, for example, California, North Carolina etc. Thus, GIS as a tool for designing emergency response mechanism is very advantageous.

2.10.3.1 Lessons learnt from the case of emergency preparedness mechanism of Allahabad city, India

Emergency preparedness mechanism is crucial for any flood management plan to reduce the damage of life and habitat. But in the developing world, most of the countries posses a severe backlog in the use of efficient tools to enhance emergency preparedness mechanism. The primary reason behind it is financial capacity and skilled manpower. The significance of the case of Allahabad city lies

here, it realized the importance of investing in technology which will in turn can reduce the damages caused by flood which is far higher than the initial investment. The mapping done by this tool effectively guided them to plan for effective strategies in response to flood hazard and thus reducing the damage to a great extent.

2.11 Conceptual framework



2.12 Conclusive remarks

The frequency and intensity of climate variability will increase in future, so do the vulnerability of the least developed countries. Therefore, effective locally driven adaptive measures are needed to be undertaken. Based on the literature review, it is found that adaptation to climate change is not only the adjustment of the system to moderate the impacts of climate change but also we need to take advantage of new and innovative opportunities, scopes to cope with the consequences. Involvement of all levels (individual, communal, local and national government, international organizations) is deemed necessary to combat with climate change. The analysis of planning approaches and strategies has pushed the research work forward. It shows the necessity of reviewing the typical traditional approach of adaptation planning and existing planning strategies, in line with the research context. As because, through adaptation assessment, all the options are evaluated, so the probability of loss and mal adaptation is lessen, which is much more crucial for the least developed countries where resources are limited and climate change risk is higher. There are different approaches and strategies incorporating different methods and objectives. The review finds UNFCCC's NAPA framework to be applicable in the research context which promotes the human development approach of adaptation planning. The analysis of the prioritization methodology helped to end up with one most appropriate qualititative approach, that is, Multi criteria analysis, which is also suggested by the UNFCCC adaptation framework for least development countries. This prioritization method takes into account different criteria at the same time which is critical for those countries where climate change has multifaceted impacts. And also enough data is not always available or it is not possible to convert all the climate change impacts in monetary terms, so conducting CEA or CBA is difficult. Moreover, the multiple stakeholders' involvement reduces the possibility of biasness as well. In the research work, the major emphasis is in assessing the adaptation measures and prioritizing of those with a view from the stakeholders and experts' judgment. The analyzed two successful cases of early warning system and emergency response mechanism are taken as proposed adaptation options for adaptation assessment.

Chapter 3: Research methodology

The central topic of this chapter is the research design, data collection and data analysis methodologies. The aim of this chapter is to structure the framework for data collection and data analysis methodologies to facilitate gathering the necessary data and coming up with the expected results. This chapter constitutes the detail framework for the data collection methodologies i.e. vulnerability assessment and adaptation assessment. Moreover, it formulates the analytical framework for the research.

3.1 Research type

Natasha (2005) in 'Qualitative Research Methods: A Data Collector's Field Guide' states that qualitative research is a type of scientific research. In general terms, scientific research consists of an investigation that:

• seeks answers to a question
• systematically uses a predefined set of procedures to answer the question
• collects evidence
• produces findings that were not determined in advance
• produces findings that are applicable beyond the immediate boundaries of study

Qualitative research shares these characteristics. According to her, one advantage of qualitative methods in exploratory research is that not using close ended questions which give participants the opportunity to respond in their own words, rather than forcing them to choose from fixed responses, as quantitative methods do.

Being consistent with the above characteristics the **qualitative exploratory research** approach has been employed in this research to explore and assess adaptation measures to reduce the vulnerability of the Eastern fringe of Dhaka city.

3.2 Research strategy

Research strategy applied in this research is *Single holistic case study* which will help to develop in depth understanding regarding the research problem.

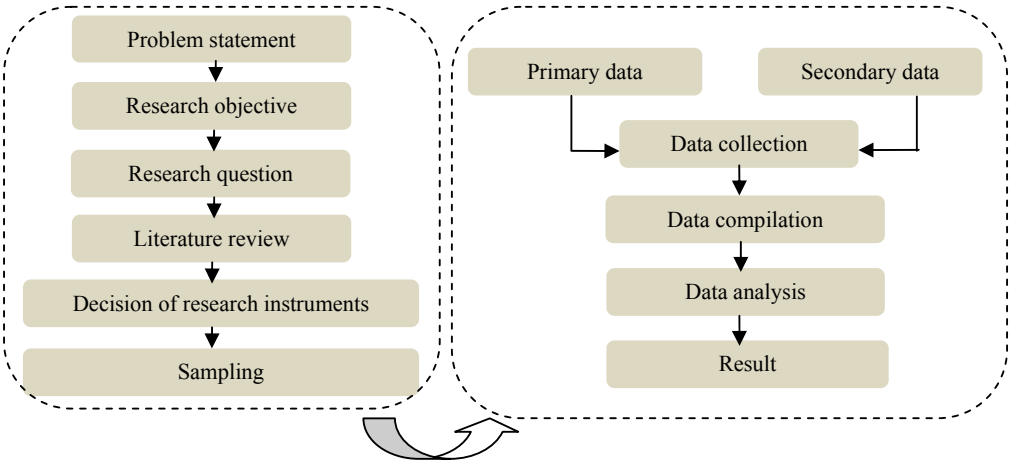


Figure 3.1: Research Design
Source: Author, 2010

3.3 Unit of analysis

The unit of analysis is the *Eastern fringe of Dhaka*. The research aims to investigate and assess the adaptation options to deal with flooding and prioritize most effective adaptation options. This entails the detail analysis of the impacts of flooding as well as the framework for the adaptation options within the specific context of flooding.

3.4 Data Collection methods

Two types of data collection methods have been applied in this research, primary and secondary data collection.

3.4.1 Primary data

3.4.1.1 Data Collection instruments

Four most common qualitative methods are in-depth interviews, focus group discussion, questionnaire survey and participant's observation. Each method is particularly suited for obtaining a specific type of data.

- *In-depth interviews (Expert judgment)* are optimal for collecting data on individuals' perspectives and experiences, particularly when sensitive topics are being explored.
- *Focus group discussion* are effective in eliciting data on the specific norms of a group and in generating broad overviews of issues of concern to the specific groups or subgroups represented (Natasha et al. 2005).
- *Questionnaire survey* is a productive tool to collect data from the sample respondents on the basis of same list of questions
- *Direct observation* is appropriate for collecting data on naturally occurring behaviors in their usual contexts.

In this research paper, all the four methods have been employed for collecting primary data.

In depth interview/ Expert judgment:

In depth interview/ expert judgment are taken in this research to score adaptation options for prioritization. In stead of questionnaire, tables are formulated with multiple criteria to have experts' judgment. Experts' judgment is undertaken to explore their expertise for the impact assessment of the adaptation options. Written notes and audio tapes have been used to record the responses as well.

Focus group discussion:

Focus group discussion as a method is very useful in exploring the stakeholders' opinions regarding the final selection and weighting of criteria. This method has facilitated to have a fruitful and healthy discussion that generated knowledge, enhanced participation, provided a learning process and assured acceptance of the final outcome. The outcome of the discussions (consensus) is the final selection and weighting of criteria. The discussion has been recorded in video tape.

Questionnaire survey:

Questionnaire survey has worked as a very useful method for collecting data from the existing inhabitants of the study area. This survey has been conducted to validate the secondary data.

Direct observation:

Direct observation of the study area is used to identify the physical aspects, land use pattern, existing adaptation measures and neighborhood status of the EFA. The observations are systematically recorded both in video tape and photographs for later analysis.

3.4.2 Secondary data

Reviewing literature related to the research topic has been done in order to understand relevant theories and information regarding vulnerability, climate change, adaptation planning approaches and assessment strategies. The required data have been gathered through desk research and also by using the source of internet. The following secondary data have been collected and analyzed:

- Documents, newspapers and archival records about the impacts of the flooding in the eastern fringe of Dhaka.
- Records and documents to identify the vulnerability of the research site to flooding.
- Records and documents regarding the initiatives undertaken by government.
- Cases with similar context in other cities around the world have been researched with a purpose of identifying the flood adaptation options with response to climate change that can be applicable to the eastern fringe of Dhaka city.
- Analysis of the policy papers such as National Adaptation Program of Action (NAPA), Flood Action Plan (FAP), National Water Policy, Dhaka Metropolitan Development Plan (DMDP), Bangladesh Environmental Policy etc.

3.5 Sampling method

Sample expert respondents are selected by using purposive sampling method based on predefined criteria. The respondents (experts) are selected based on their expertise in the climate change adaptation and flood management sector i.e. vulnerability assessment, impact assessment, adaptation assessment, flood management. An advantage of snowball sampling has been taken as it arose during the in depth interview. A group of seven experts are selected based on their expertise. Table 3.1 is showing the selected bodies from which the experts are chosen.

Table 3.1: List of Respondent expert institutions

Name of institution	Type of institution
Bangladesh Center for Advanced Studies (BCAS)	Local NGO
Japan International Corporation Agency (JICA)	International NGO
Department of Environment	Government
Bangladesh Water Development Board (BWDB)	Government
Dhaka Water and Sewerage Authority (DWASA)	Government
Roads & Highways Department (RHD)	Government
Institute of Water and Flood Management, BUET	Semi – Government

Potential stakeholders are also selected by purposive sampling. Total eight respondents are selected for the focus group discussions. Due to short time period for data collection, it is not possible to take into account all the relevant stakeholders. Community representatives represented the most affected communities of the study area, representatives from the small business and farmers' community have also been represented, three most vulnerable infrastructure sectors have been taken into account and also the non governmental organization (NGO) dealing with social and development objectives of the study area are represented in the stakeholder group. There is no active women organization working in the study area. But the gender aspect has been presented by the NGO involved with the social and development objectives of the study area and also by the community representatives.

Table 3.2: List of Respondent stakeholders

Stakeholder	Area/organization
Community representatives (Ward commissioner)	Study area
Representatives from 'small business and farmer community'	Study area
Government departments responsible for vulnerable infrastructure sectors	BWDC, DWASA, RHD
NGO involved with the social and development objectives	BRAC

For the questionnaire survey, sample respondents have been chosen using random sampling method.

3.6 Data quality

3.6.1 Reliability

Reliability is the consistency of measurement, or the degree to which an instrument measures the same way each time it is used under the same condition with the same subjects[18]. Triangulation method will be employed to ensure the consistency of the research. According to O' Donoghue and Punch (2003), triangulation is a "method of cross-checking data from multiple sources to search for regularities in the research data". There fore, data have been collected from different sources like primary data (i.e. focus group discussion, questionnaire survey, experts' judgment, direct observations) and secondary data. Scoring of the same adaptation measures under same criteria by different experts has served as a way of cross checking the responses. This has helped to verify the accuracy of the collected data.

[18] See http://www.socialresearchmethods.net/tutorial/Colosi/lcolosi2.htm

3.6.2 Validity

Validity refers to the extent to which the chosen research instrument accurately measures what it is intended to measure. This qualitative research outcome is based on expert judgment which is validated by their expertise itself. The secondary data for adaptive capacity analysis is validated by the questionnaire survey. The stakeholders' assessment is validated by the focus group discussion with the selected stakeholders. Moreover, video recording has been carried out during the discussion to ensure validity.

3.6.3 Objectivity

Neutrality is maintained while structuring the criteria for the scoring of the experts, since it has been finalized by the stakeholders themselves through focus group discussion.

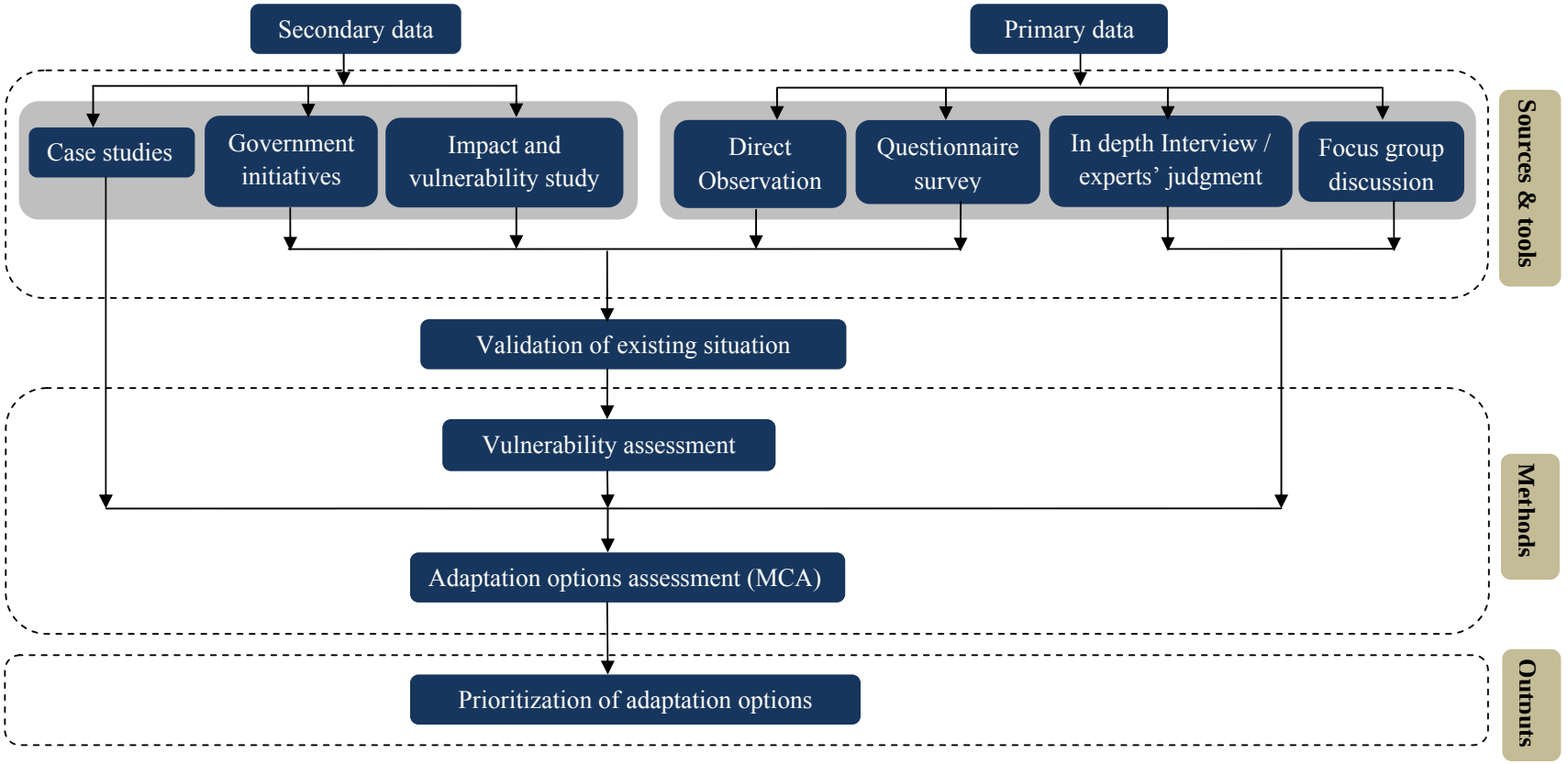
3.7 Data analysis

Multi Criteria Analysis method (MCA) is applied to analyze data. The procedure is inspired by NAPA guidelines for MCA. NAPA process uses this MCA method to allow the least developed countries to identify the critical and immediate needs of adapting to adverse effects of climate change and identify and prioritize adaptation options to fulfill those needs[19]. This analytical method of MCA has been assisted by an excel based tool, namely Multi Actions Prioritization Analysis and Decision Support Tool (MAPA - DST) developed by IHS.

[19] See Box 2.3

3.7.1 Analytical Framework

The analytical framework of this research illustrates the research process of this study. It shows how the data collection and data analysis is done in order to meet the research objectives.



3.7.2 Steps for analyzing data

3.7.2.1 Step 1- Decision making context (Vulnerability assessment)

The first step is to prepare an Exposure index of current climate hazards. Exposure of the study area to flooding is analyzed by assessing the factors which determines exposure, i.e. frequency, spatial extent, duration of different types of current flooding hazards. To perform this job, secondary data has been collected by desk research.

The next step under this decision making context is to create a Sensitivity matrix to identify the sensitivity and impact index. The impacts of specific flooding hazard to the most significant sectors/ capital assets for the study area have been assessed for this analysis. This is done based on secondary data on the impacts of floods of last three decades.

Analysis of the adaptive capacity is done based on available secondary data and the questionnaire survey on the study area to identify the factors that affects adaptive capacity, i.e. income level of the inhabitants, education/ awareness, existing infrastructure services etc. In depth analysis of adaptive capacity is beyond scope because of the limitation of time.

Then the final step for vulnerability assessment is to prepare vulnerability index based on the exposure index, sensitivity index and adaptive capacity of the study area.

3.7.2.2 Step 2: Selection of potential adaptation options based on Vulnerability index

According to the vulnerability index, adaptation options are selected for assessment.

3.7.2.3 Step 3: Criteria identification

Criteria are selected in a participatory manner keeping in mind the most significant considerations for the adaptation options. These criteria are finalized by stakeholders through focus group discussion. Criteria must fulfill some qualitative attributes as described by Hajkowicz et al. (2000), Belton and Stewart (2002) and Grafakos et al. (2010):

- *Value relevance* – Linking the concept of each criterion to the objectives it is meant to represent.
- *Operationality* - Evaluation criteria should be able to identify how well each option of policy interaction meets the objectives expressed by the criteria.
- *Reliability* – A malfunctioning criterion should not render the whole set of criteria unworkable.

- *Measurability* – Degree of measurement of the performance of alternatives against specified criteria.
- *Decomposability* – Possibility to break down an objective into specific means.
- *Non-redundancy* – Limiting the number of criteria addressing the same objective, meaning avoidance of duplication of information in criteria.
- *Minimum size* – The number of criteria employed should be only the absolutely necessary to provide representation of policy objectives.
- *Preferential independence* – Preferences associated with the performances of each option should be independent of each other from one criterion to the next.
- *Completeness* – The selected criteria should cover all the key elements of the evaluation problem.
- *Understandability* – The selected criteria should be understandable not only by specialists but by non technical people too.
  Keeping in mind the above mentioned attributes, the criteria have been selected.

3.7.2.4 Step 4: Scoring of criteria per adaptation option

The next step is to score each adaptation option against specific criteria. This step is done by the experts' judgment. Experts scored each adaptation option based on their expertise.

3.7.2.5 Step 5: Standardization of options

After the scoring of adaptation options, the scores have been standardized. Different units used to score the criteria, have been standardized to a common scale with the aid of the excel based tool for MCA.

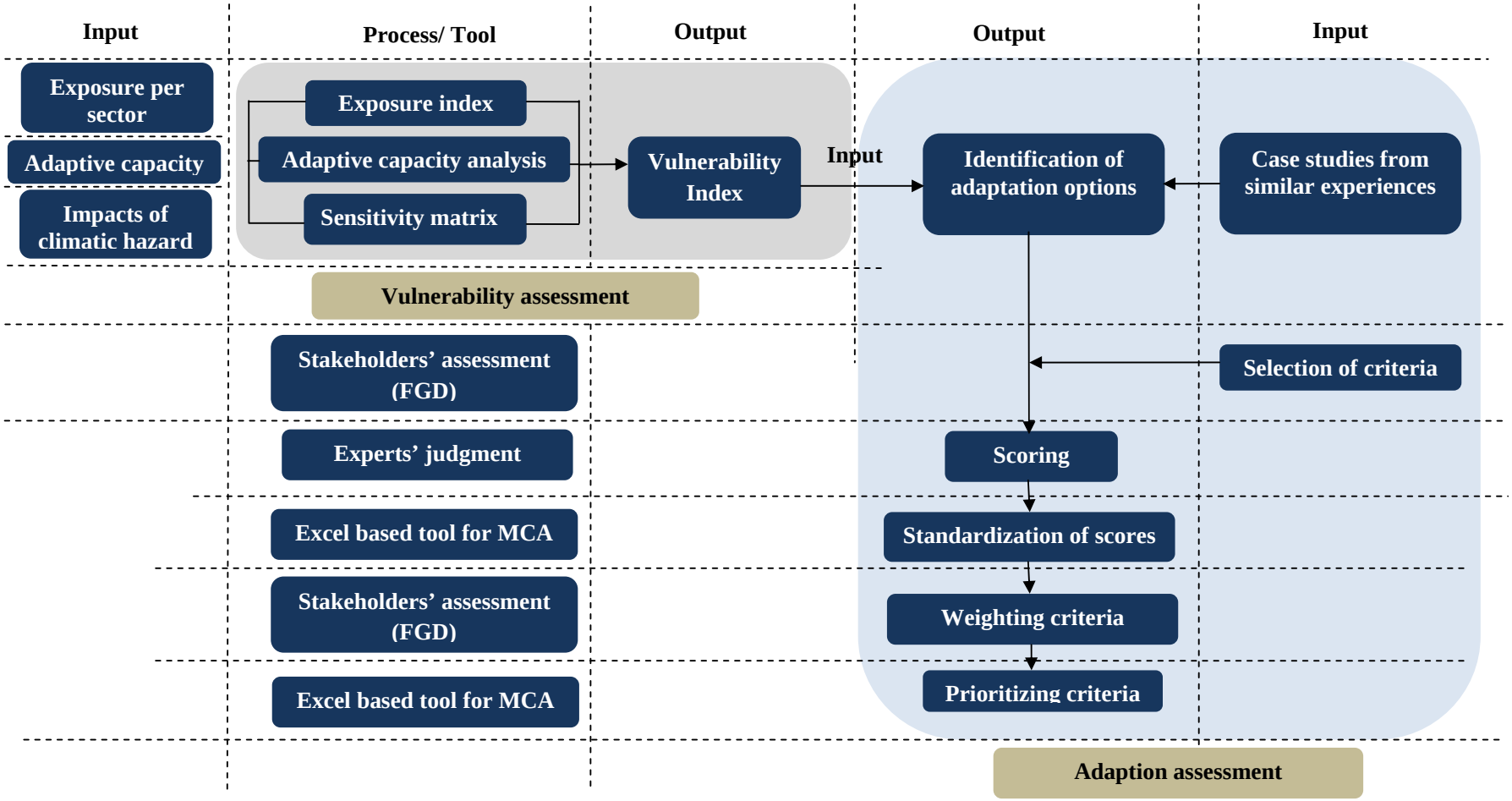
3.7.2.6 Step 6: Weighting of criteria

Weighting of criteria is done based on the degree of importance of each adaptation option. Stakeholders' assessment is used for eliciting their preference to weigh the criteria. Stakeholders' assessment is undertaken through focus group discussion. Therefore, the weighting is resulted from the discussion as consensus.

3.7.2.7 Step 7: Prioritization of options

This is the last step for the whole data analysis. It is resulted with the final outcome of the prioritization of the most efficient adaptation measures for the study area.

3.7.3 Data analysis scheme



3.8 Resources

The resources include those required to fly to and from Bangladesh to conduct the data collection for the research. Time management, psychological skill and attitude during the interviewing and discussion are considered to be fundamental resources for conducting the research. And also, five research assistants were employed for the questionnaire survey. Above all, the constant guidance of supervisor through out the whole research period is the supreme resource for the research work.

3.9 Scope and limitations of the study

- The scope of study lies on the geographical location of the area and the focus on flooding, since it is the most vulnerable part of Dhaka city to flooding.
- The research is limited by the short time period for data collection[20].
- The study is focused on most affected sectors related to flooding rather than covering all the affected sectors, because of the time limitation.
- Because of the short time period, the research has to rely on secondary data to a certain extent for validating existing situation.
- In depth vulnerability assessment and adaptive capacity analysis is not possible within the short time period.
- True picture revealing regarding the government initiatives is somewhat hampered because of the unwillingness of the government officials.

3.10 Summary

The research typology is stated in this chapter to be qualitative exploratory research in nature. Primary and secondary data have been collected. In depth interview/ expert judgment, focus group discussion, questionnaire survey and direct observation are used as primary data collection instruments. Purposive sampling method has been adapted for selecting experts and stakeholders and random sampling method has been used for questionnaire survey. The unit of analysis is the study area itself. Focus group discussions are done for stakeholders' assessment in order to weigh the criteria and direct observation will help to identify the physical aspects, land use pattern and existing adaptation measures of the area. All the data collected using the list of variables and indicators[21] are analyzed according to the guidelines of NAPA framework. Therefore, vulnerability assessment, scoring of adaptation options by expert judgment and weighting of adaptation options by stakeholders' assessment are done in order to prioritize options.

[20] See Annex 4
[21] See Annex 5

Chapter 4: Overview of the study area

This chapter presents a brief overview of the Eastern fringe area. It includes a brief description of Dhaka city and study area, i.e. context of the site, urbanization trend, climate, natural drainage system, eco system. It has also attempted to identify the land profile and typology of the study area. And last but not the least, flood dynamics of Dhaka East is explained here as well in terms of flood typology.

4.1 Description of the study area

The area of Dhaka Metropolitan City is nearly 1530 sq. km and an estimated population of 9.3 million live in this city[22]. According to the most recent UN estimate, its population will reach 19.5 million by 2015. The area under Dhaka city corporation is about 360 sq. km with a population of 5.94 million[23]. The planning of a by pass road for Dhaka city is encouraging the expansion towards more eastward due to locational advantage and close proximity to the Central business District (Figure 4.1). Areas covered by Dhaka East is 119 km^2. The proposed study area in the eastern fringe of Dhaka is defined as the zone in between Progoti Sarani on the west, Balu River in the east, Dakkhinkhan on the north and Begunbari Khal on the south. The area is about six to seven kilometers north east of the CBD. Apart from small portion in the northwest and southwest, the area is drained east to the Balu river. It forms some two third of the greater Dhaka drainage basin.

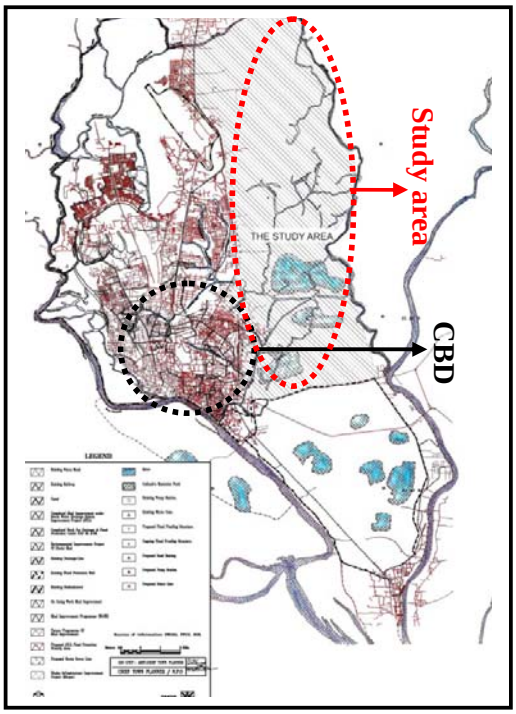


Figure 4.1: Location of the study area in the Dhaka city map
Source: Adapted from the Geographical Information Systems Division of Bangladesh Centre for Advanced Studies, 2009

Eastern fringe is defined as flood flow zone for the drainage, navigation or retention of urban runoff in the structural plan proposed for 1995 to 2015. The high rate of migration is increasing the population of Dhaka, and 30% of the population is below poverty level living in informal settlements. These settlements are mostly in these low lying areas of Eastern fringe. The flood plains adjacent to the Balu river are predominantly agricultural lands for cultivation. Diversified local fishes are found in the perennial water bodies and these are potential areas for open capture fisheries (JICA, 1992). But these water bodies are rapidly decreasing because of the land filling by the private developers even after the ratification of Water Body

[22] See http://www.dhakacity.org/Page/About_us/About/Category/2/About_us_info
[23] See http://www.bdix.net/sdnbd_org/world_env_day/2005/bangladesh/index.htm

Conservation act, 2000 according to which any kind of development is prohibited in the wetlands.

4.2 Climatic conditions and flooding

Climatic conditions in Dhaka are categorized as 'Tropical monsoon' with four annual seasons i.e. monsoon, post- monsoon, dry and pre monsoon. The monsoon or rainy season is mainly from May to October. 90% of annual rainfall (2000 mm approx.) falls during this monsoon period. Cyclones with strong winds hit Bangladesh very frequently during the monsoon and post monsoon periods which sometimes lead to storm surge in the coastal area. But Dhaka is out of the storm surge affected area.

4.3 Natural drainage

Dhaka East drains mainly into Begunbari canal and Jamir canal which is connected to Balu river. Therefore, mainly these two canals along with the Balu river produces the principal natural drainage network of the EFA.

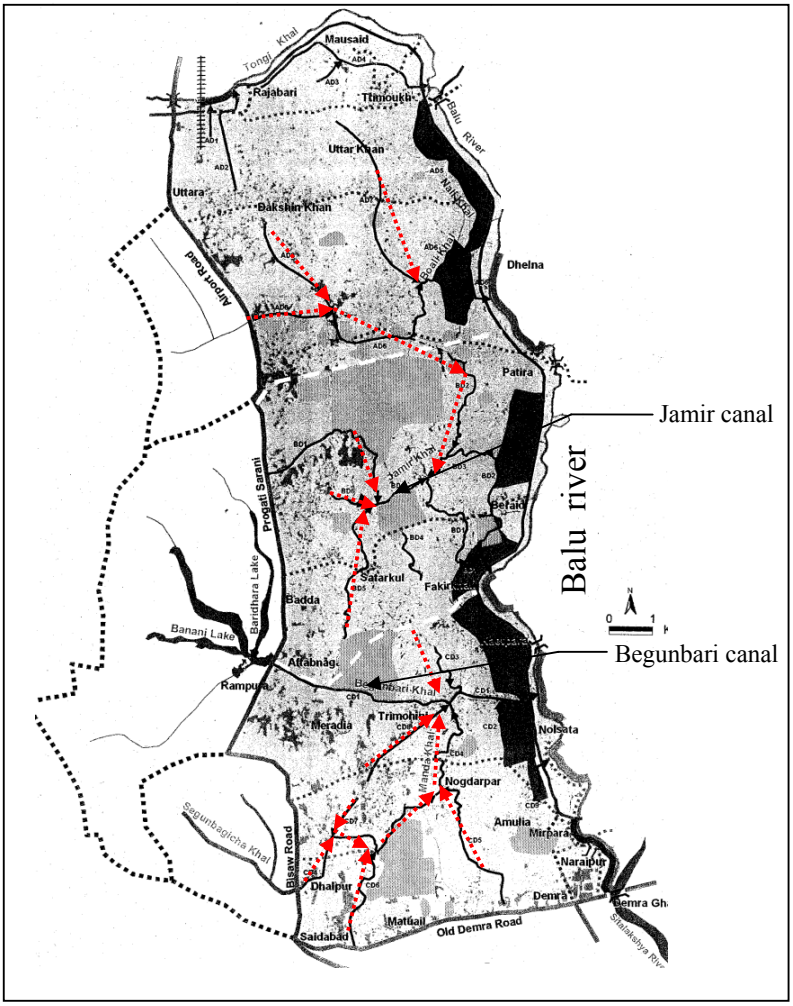


Figure 4.2: Natural drainage system of the study area

Source: Halcrow Group, 2006

4.4 Ecosystem

The ecosystem of the study area consists of higher ridges which is typified by red soils and lower inundated areas typified by darker clays. The lower areas are mainly single crop areas of agricultural land and also highly significant because of fisheries and natural wetlands vegetations. Out of 265 fresh water fish species, more than 70 fish species are found in the EFA. The total number of identified floral and faunal species in the study area are 122 and 80 respectively.

L-R: Wetlands and aquatic habitat, low lying area used as agricultural land

4.5 Land use typology

The DMDP (Dhaka Metropolitan Development Planning) areas have been divided into 26 spatial planning zones and subzones (SPZs). The area in between Pragati Sarani and River Balu (SPZ-12) is defined as Eastern fringe which is characterized as *low lying* area with predominant *existing mixed use spontaneous zone* and *planned residential area* developed by Private companies. Dynamics of the growth is identified as '*Densifying*' indicating *more people are coming in*. Area at outskirts of the eastern fringe which is bounded by Balu and Lakhya River is documented as Razuk East (SPZ-19). The area is mainly sub urban in character with industrial development. Land use map of Dhaka, 1976 shows that the land use characteristics of this area is rural. Later, private owners converted this land predominantly for residential use. The fast pace of development in the area is evident from figure 4.4 & 4.5.

4.6 Land profile of the study area

According to DMDP, the land of the study area can be categorized into two types. One type, which can be called higher land, is mostly riverine flood free area with an elevation of more than 5m. The other type can be called lower land which is flood prone. The higher land is situated along western edge, being to the north in Uttara east and also from Khilgaon to Jatrabari in the south.

A few decades ago, more than half of this land was under water. Majority of the land in the middle part has an elevation of less than 2.5 meters.

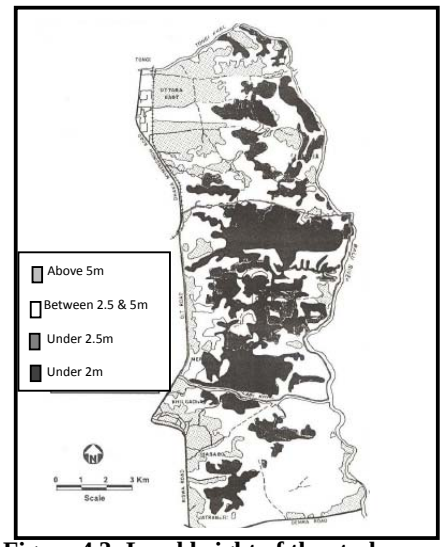


Figure 4.3: Land height of the study area
Source: FAP 8A, JICA, 1992

Significant amount of land filling took place here to elevate the level of the low land for development. The whole region consists of a semi-aquatic environment, regularly flooded by the Balu river and Begunbari, Fakir, Jamair, Dumri and Jirani Khals.

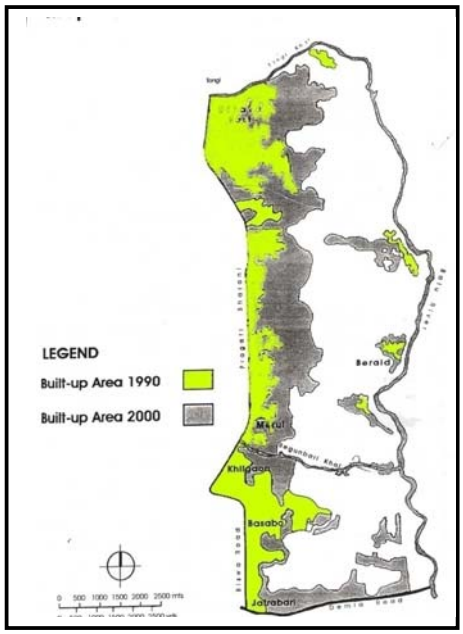


Figure 4.4: Increase of built up area
Source: FAP 8A, JICA , 1992

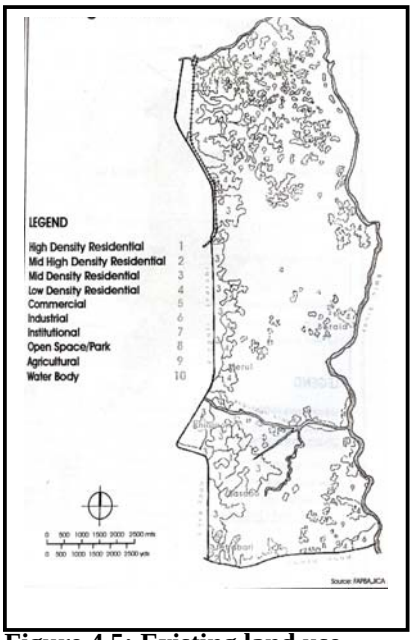


Figure 4.5: Existing land use
Source: FAP 8A, JICA , 1992

According to the FAP 8A (JICA 1992), about 78% land is being used for agricultural purpose, particularly in the lean season, 12.5% for settlements and 10%for water bodies/wetlands. Extent of urban settlement was much less significant in 1995 than in 2006. In 1995, 9.6 hectors of land was designated for urban use, which increase to 22 hectors by the year 2006. Figure 4.6 shows the decrease of wetlands and agricultural land in EFA for a period of 1996 to 2010.

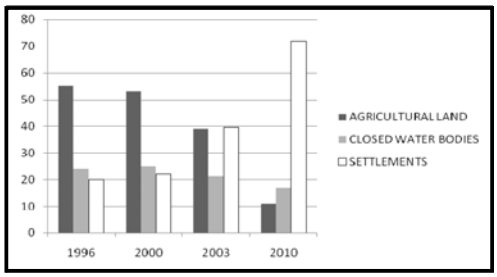


Figure 4.6: Decrease of agricultural land and water bodies with the increase of human settlements

Land filling and ongoing development by encroaching wetlands

4.7 Flood dynamics

The flood risk in Dhaka EFA can be broadly classified into two types:

- River floods, which is generated by a number of flood mechanisms, the basic control of which are seasonal flows in the Ganges, Brahmaputra and Meghna rivers.
- Localized or urban flooding are caused by heavy rainfall and compounded by inadequate drainage facilities. This can be again classified into two categories, one is *storm water flooding* and the other is *rainfall induced flooding*.

4.7.1 River flooding

Every year, river flood inundates the huge study area creating severe sufferings to the inhabitants as well as degrading environment. Riverine flooding usually submerges the agricultural lands and low lying homestead areas scattered in the floodplain areas, but sometimes it goes beyond like it happened in 1998, 1988 floods.

The factors on which pre-monsoon and full monsoon river flooding are predominantly dependant as stated by the Halcrow report (2006) are:

I. Volume of flow that come through old Brahmaputra river
II. Internal flooding caused by storm water flooding due to insufficient drainage facilities in the built up areas
III. Back water from Meghna river, if there is a heavy rain in the northeastern part of Bangladesh and a high tide in Bay of Bengal at the same time.

In 1988, the catastrophic river flooding was assessed to be of a magnitude equivalent to a 1: 70 year return period. Almost the whole Dhaka East was inundated. 1998 river flooding was also a catastrophic one inundating almost 80% of Dhaka East.

4.7.2 Localized or Urban flooding

It is a regular event in Greater Dhaka East area affecting about 12% of urban area each year. On an average this causes up to 0.6m flood depth for a period of 4days. The main factors behind it are:

I. Heavy rainfall
II. Malfunctioning and nonexistence of the drainage system
III. Rapid unplanned development of the urban areas and encroachment of wetlands
IV. High river flood level in the floodplain areas which are connected to the urban areas.

In 1986, localized flooding affected 12% urban area and the flood depth was 1m for over a 6 days period. The main cause of the 2004 urban flood was intense

storm for a period of 4 days. This time as well almost the whole study area went under water.

4.7.3 Flooding characteristics

It is evident that, Dhaka East is being regularly damaged by urban flooding on a more or less similar scale to that of a river flooding of about a 1:10 year return period. According to Halcrow report (2006), at least 12 to 15% of Dhaka EFA is regularly affected by flooding. If the encroachment of wetlands is continued, the impacts of both types of flood will increase.

4.8 Summary

The EFA is quite rich in ecosystem with a wide variety of fisheries, flora and fauna. It basically consists of low lying areas and is considered to be highly flood prone. The climate of Dhaka is also very much in favor of flooding with a high intensity of rainfall. Flooding in EFA is basically caused by overflowing the river, extensive rainfall and storm. And every year a significant portion of it is flooded. Being near to CBD, the urbanization rate in Dhaka East is very high. The land use typology is changing very fast. About three decades ago, it was stated to be rural. Now, it has changed to be densifying indicating more people coming in. And in this process, the wetlands of the area are decreasing in the name of development. These wetlands actually constitute a major part of the whole Dhaka city drainage. This situation is aggravating the risk of flooding in the study area.

Chapter 5: Research findings and analysis

This chapter entails the findings of the research and analysis based on the research questions. Government initiatives undertaken (proposed adaptation measures) to address the problem of the study area of flooding are also taken into light in this chapter. This analysis is led to the prioritization of adaptation options. In this process, the most vulnerable sectors to flooding have been identified by investigating the impacts of different types of flooding hazards. The criteria needed to be considered in the adaptation assessment are identified as well.

5.1 Proposed adaptation measures

After the catastrophic floods of 1987 and 1988, GoB envisaged Flood Action Plan (FAP) to protect the country from flood damage. Various proposals have been studied since then, to protect Dhaka East from flooding. 1992 JICA FAP 8A study was the first one. In 1996, a feasibility study of the project was done by Halcrow Group. Dhaka East is planned to be protected under Dhaka Integrated Flood Control Embankment cum Eastern Bypass Road Multipurpose Project which aims to enhance social, financial and economic welfare of the communities living in the Dhaka East. Under this project, a 100 year standard of protection is adopted.

5.1.1 Project interventions

Following interventions have been proposed according to technical considerations of the project:

Sl. No.	Name of interventions	Quantity (km/nos)
1.	Flood embankment	24.4 km
2.	Pumping stations	3
3.	Regulators/ sluices	9
4.	Retention basins	3 (930ha)
5.	Construction and upgrading of road network	27.2 km
6.	Flood walls	3.4 km
7.	Canal improvement	78.4 km

Total project cost at constant 2005 prices is estimated at US $ 338 million including all contingencies. After the catastrophic floods of 1998 and 2004, updating and upgrading of the previous studies were initiated. But still now the project is not being implemented though successive governments have been declared it to be a priority project. It has been twelve years since the project has been approved (1998)[24]. In August 2010, the prime minister of Bangladesh declared to revive the project in near future which was suspended in 2003. BWDB would be the leading agency for the execution of the project.

5.2 Exposure Index

The first step of vulnerability assessment is to prepare an Exposure index of current climate hazards. Table 5.1 shows the list of current flooding hazards in Dhaka and the exposure of the study area to those hazards. This table is filled with

[24] http://www.thedailystar.net/newDesign/news-details.php?nid=123681

the secondary data gained from desk research to identify the Exposure index to specific hazard.

Table 5.1: Exposure Index

Hazard	Frequency	Duration	Spatial extent	Exposure Index (E.I)
Riverine flood	2	3	3	**0.89**
Rainfall induced flood	3	2	2	**0.78**
Storm water flood	1	1	2	**0.44**

Notes:

Scoring criteria:

Frequency: 1= Certain years; 2= Annual; 3= more than once in a year
Duration (days): 1=Less than 20; 2=20-50; 3= over 50
Spatial extent (km²): 1= 1-10; 2= 11-50; 3= over 50
Each hazard has given a score on a scale ranging from 1 to 3. The Exposure index is then calculated by adding up all the scores for each hazard and dividing the total score by 9 (3 per factor). For example, the exposure index for rainfall induced flood is: 3+2+2=7/9=**0.78**.

Explanation of exposure index:

The exposure index shows that the study area is highly exposed to riverine flood. Dhaka is less exposed to rainfall induced flood than riverine flood. Storm water flood is last in the list because of comparatively less frequency and duration than the other two types of floods.

5.3 Impacts of previous catastrophic floods

Within last two decades, Bangladesh experienced major floods in 1998, 2004 and 2007. One of the most catastrophic floods in the history of Bangladesh, occurred in 1998 (riverine flood). Whole Dhaka East went under water. Water supplied by the central water supply system was found to be contaminated by coliform bacteria. Flood water mixed with congested sewage (due to poor sanitation system) gave birth to water borne diseases. Huge housing damage had been reported during that period. Plants and trees were directly affected due to prolonged inundation. Air quality was severely deteriorated, on an average 50% more suspended particulate matter is found in the air during the inundation period (eds. Nishat, 1999).

Disruption of communication due to flood
Source: The Daily Star, 15 August, 2005

Education system was highly affected because of the absence of students in the school which had multiple reasons, inundation of road and school building, health disease etc. Loss in trade sector was also intensive.

The latest catastrophic riverine flood occurred in 2007 had huge impacts on Dhaka East. A good number of people have been reported to fall sick drinking contaminated water. Specifically, the health cases of diarrhea had passed all the last records during this flood. Most of Dhaka East was inundated and contaminated water went into the drinking water supply pipeline due to the poor condition of the pipelines (Islam et al. 2008). This resulted in increased water borne diseases in the Dhaka East.

A few years back from 2007, in 2004, there was another catastrophic storm water flooding causing huge damage to the study area. Due to poor status of flood forecasting, substantial damage in the agriculture sector occurred, though the flooded area was much lower than the previous floods. But if the damage is monetized, the damage of infrastructure supersedes damage of crops. Also electricity disruption occurred due to inundation of power grids (Rahman et al. 2005).

Apart from these catastrophic floods, every year Dhaka East is being flooded during the monsoon period causing significant damage.

L-R: Inundated household, search for drinking water, submerged power grid
Source: L-R- http://static.wix.com/media/c2654930d4f980568c896a7f1f79a1a5.wix_mp , http://www.instablogsimages.com/images/2007/08/09/dhaka-flood_58.jpg, Islam et al. 2008

5.3.1 Sensitivity matrix

The next step under the decision making context is to create a Sensitivity matrix to identify the sensitivity and impact index. The following table 5.2 is formulated with the most significant sectors/capital assets of the study area and scored based on available secondary data on the impacts of floods of last three decades.

Table 5.2: Sensitivity Matrix

Types of capital assets		*Climatic hazards*			**Sensitivity Index (S.I)** (Scale 1 -100)
		Riverine flood	Rainfall induced flood	Storm water flood	
Natural	***Ecosystem***[25]				
	Flora and fauna	4	3	2	**60**
	Water quality	5	5	4	**93.33**
	Air quality	4	3	1	**53.33**
	Soil contamination	4	2	1	**46.67**
Physical	***Property , goods and services***[26]				
	Shelter/ housing and other assets	4	3	2	**60**
	Infrastructure	5	4	4	**86.67**
Economical	***Productive sectors***				
	Agriculture	3	3	4	**66.67**
	Trade	5	4	3	**80**
	Fisheries	3	2	1	**40**
Social	***Stakeholders/ livelihoods***				
	Squatter and slum dwellers	5	3	4	**80**
	Land owners	3	2	1	**40**
	Tenants	2	1	1	**26**
	Agricultural workers	4	2	3	**60**
	Traders and businessmen	4	3	3	**66.67**
	Impact Index (Scale of 1-100)	**72**	**44**	**48**	

Notes: Each type of capital asset has been given a score on a scale ranging from 1 to 5 (1 stands for lowest and 5 stands for highest) to indicate its sensitivity to specific climatic hazard. Then, the sensitivity index is calculated by adding up all the scores that each type of capital asset has received and dividing that total score by 15 since 15 is the highest possible score (5 per sector) and finally multiplying by 100. For example, the sensitivity index for squatter and slum dwellers is: 5+3+4=12/15=0.8 X100= **80.**

The impact index is only calculated for the stakeholders/ livelihood category. Therefore it is not necessary to calculate the impact index for all categories. The index is calculated by adding up all the scores per climatic hazard for the stakeholder/ livelihood category, then dividing it by 25 (5 per sector) which is the possible highest score and multiplying by 100. For example, the impact index of the stakeholders for riverine flood is: 5+3+2+4+4=18/25=.72 X 100= **72**.

[25] See Annex 6
[26] See Annex 7

The sensitivity index illustrates the degree or level of sensitivity of each type of capital asset to climatic hazards, while the impact index allows the identification of the level of impacts of specific climatic hazard on stakeholders. While analyzing the impact index, the frequency of occurrence of specific climatic hazard was kept on mind, for example, flood caused by storm water has a much lower frequency than the rainfall induced flood.

Explanation of Sensitivity index:

The sensitivity index shows that *water quality* (natural asset) is the most sensitive sector due to flooding bearing a very high (93.33) index. Then the next sensitive sector is the *infrastructure* (physical asset) having an index of 86.67. *Trade* (economical asset) is also very sensitive to flooding bearing an index of 80. While Impact index shows stakeholders/livelihood are highly affected by riverine flood while the impact is much less for the other two types of flood compared to riverine flood.

5.4 Adaptive capacity

5.4.1 Demographic characteristics

The population of the study area is 13,49,808[27] and the number of households are 2,81,210 (Halcrow Group, 2006). Density is around 11,000 per sq km. The average size of household is 5.1 against the national average of 4.8. The secondary data has been taken from the Halcrow report (2006) on 'Updating/Upgrading the feasibility study of Dhaka Integrated Flood Control Embankment cum Eastern Bypass Road Multipurpose Project'. It was conducted on 6,152 population (0.5% of the total population of EFA) in 1200 households (0.43% of the total households of EFA)[28]. To verify the gap of 4 years period a questionnaire survey[29] on 255 people in 50 households (25 households per ward) was conducted in two wards which are most densfied and near the CBD (Purba Rampura, Ward no. -22 and Moddho Badda, Ward No. - 21).Both survey finds approximately 56 percent male and 44 percent female. The male female ratio in the study area is 123.7, while that for Dhaka is 122.9 as per statistical year book of Bangladesh, 2001. Informal in depth interviews were undertaken with 10 households selected based on three different types of housing system covering all the three major income groups, where 65% respondents were female.

Table 5.3 Population distribution by sex (Secondary data)

Sex	No.	Percentage (%)
Male	3405	55.3
Female	2747	44.7
All	6152	100

[27] Based on 2001 census, Halcrow report (2006) projects the population for the study area will be 15,81,000 by 2015, 18,53,000 by 2025 and 2,172,000 by 2035.
[28] See Annex 8
[29] See Annex 9

Table 5.4 Population distribution by sex (Primary data)

Sex	No.	Percentage (%)
Male	143	56.08
Female	112	43.92
All	255	100

5.4.2 Age composition

Both the surveys find approximately 70% of the surveyed population falls under the working age group, that is, 15-59 years. The other two groups, that is, under 14 years and above 60 years are usually dependant on them for their livelihood. The dependence ratio for the secondary data and the primary data is respectively 69:31 (Table 5.5) and 71:29 (Table 5.6).

Table 5.5 Population distribution by age (Secondary data)

Age group	No.	Percentage (%)
1-14	1446	23.5
15-59	4232	68.8
60 and above	474	7.7
Total	6152	100

Table 5.6 Population distribution by age (Primary data)

Age group	No.	Percentage (%)
1-14	53	20.8
15-59	182	71.4
60 and above	20	7.8
Total	255	100

5.4.3 Occupational distribution

From both surveys, business, service and contractual work are found as major occupation as well as sources of income for the people residing in the study area. The survey results show that the highest percentage (above 35%) of the surveyed population depends on small or large scale business (trade) which is highly impacted by flooding[30]. For approximately 25% of the surveyed population, service is the main occupation. On an average 17% people live their livelihood by contractual work. 8.5% is found to have no occupation (those household heads are mainly housewives and old) by the secondary data, which is quite less in case of primary data, that is, 2%. It can be clarified since the primary data has been collected from the area near CBD, so the rate of unemployment is less. Also in case of farming as occupation, which is 10% as per secondary data and 4% according to the primary data shows that, the involvement of urban households with agriculture is minimal.

[30] See table 5.2

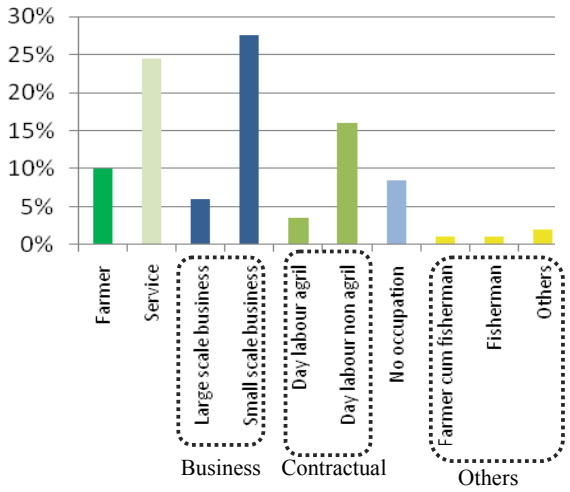


Figure 5.1: Population distribution by occupation (Secondary data)

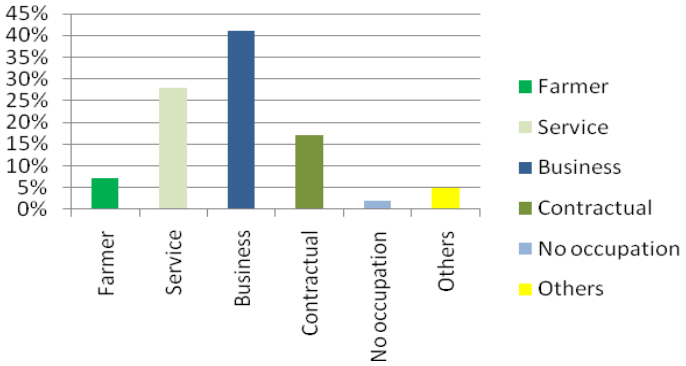


Figure 5.2: Population distribution by occupation (Primary data)

5.4.3.1 Gender aspects of occupation

In accordance to the secondary data, 80% women of the study area are engaged in household activities like vegetable gardening, poultry and livestock rearing.10-15% women work in garments, industries, government and non government offices and the remaining 5% work as wage laborer.

Woman rearing cattle

5.4.4 Annual income

In case of average annual household income, majority of the surveyed population falls under the income group of $1540- $3429[31], which is above 35% in both the

[31] All the currency in the study is US $ with an exchange rate of 1US$ = 70 Bangladeshi taka (BDT)

surveys. According to World bank (2005), people earning $1.25 per day falls under the poverty line. In line with that, more than 1.7% people of the study area falls under the poverty line according to the secondary data, which is slightly lower in case of the primary data. Since the area under primary data collection was near CBD, employment rate and average income is comparatively higher. Though insignificant (less than 0.35%), but still there are people in the study area who earns less than $169 per annum. Around 25% people earns within $860-$1539 per annum. The average annual household income is estimated $1000 at national level in the year of 2000 as of HIES: 2000, Bangladesh Bureau of Statistics (2003). Majority of the surveyed population of the study area falls within or above that.

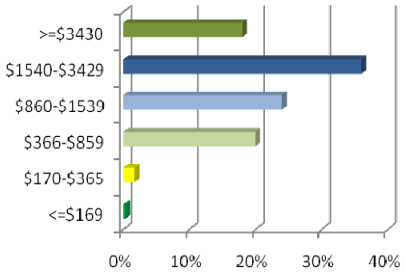


Figure 5.3: Population distribution by annual income (Secondary data)

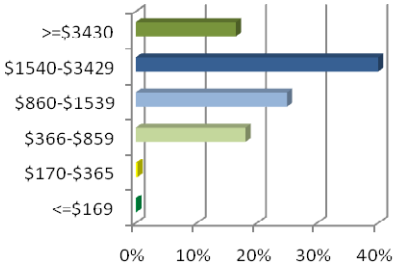


Figure 5.4: Population distribution by annual income (Primary data)

5.4.5 Education

People described the status of the education in the study area while focus group discussion and also during the informal in depth interviews. Road network and institution premises are inundated even with an insignificant rainfall. Therefore, school attendance of students is affected. Besides, school and colleges remain closed during the flood, they are used as shelter for flood affected people. Students' education in the EFA is thus hampered due to every year flood. However, the household survey shows the statistics for the education level of the study area which is presented in the following charts:

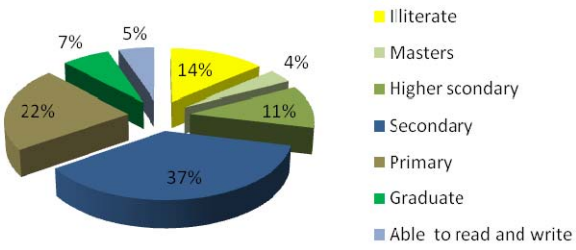


Figure 5.5: Population distribution by education level (Secondary data)

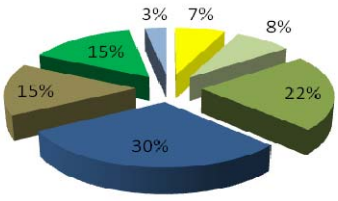


Figure 5.6: Population distribution by education level (Primary data)

The seocndary data shows 14% people are illeterate in the study area which is 7% in the primary data. This deviation can be explained as the area surveyed for primary data is near CBD so the number of schools are higher, and thus the

average education level is also higher. Among the literate people, no less than 3% people are able to read and write only. It means, they have no formal education. According to the secondary data ,the litracy rate in terms of having formal education is 81% which is 90% in case of primary data. It shows the accesibility of people to education in the areas near CBD is higher.

5.4.6 Housing typology

The surveys find three types of structures in the study area on the basis of materials used for the construction of the house. They are permanent, semi permanent and temporary structures. Temporary structures are made of thatch/mud/corrugated iron sheet (CIS)/ wood wall and thatch/CIS/tile/wood roof. The permanent houses are made of brick/cement wall with brick/cement or cement/ concrete roof. Semi permanent structures have permanent walling system but temporary roofing system made of CIS/tile/wood roof.

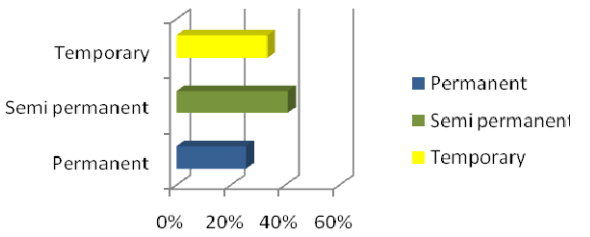


Figure 5.7: Housing typology (Secondary data)

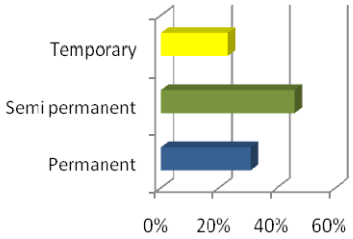


Figure 5.8: Housing typology (Primary data)

In the secondary data, among the 6,152 households surveyed 25.6% is permanent structure, which is 31% in case of the primary data. 41% and 46% are the semi permanent structures respectively for secondary and primary data. The rest are temporary structures.

L-R: Permanent, semi permanent and temporary housing in the study area

5.4.7 Existing infrastructure

5.4.7.1 Water supply system and water quality

It is found by the secondary data that, majority people of the study area depend on tube well and tap for drinking water, the percentage is respectively 55.6% and 43.4%. Very few households drink water from river, dug well, pond and canal.

From the informal in depth interviews, it is found that people use tap water for all purposes like drinking, washing, bathing etc. There is tap water supplied by WASA but it is claimed to be insufficient and also in some places contaminated with sewerage water. The well offs are used to buy mineral water for drinking. Poor people use surface water (river, pond and canal) during monsoon, but in dry season it cannot be used because of severe pollution. Some people own tube well, and many other is found to use that by monthly payment basis. But during the flooding, these tube wells submerges and the situation deteriorates. Some respondents have reported that their tube well water is contaminated with arsenic which is a crucial problem in some areas of Bangladesh. Overall, majority of the surveyed population (64%) are not satisfied with the water supply system and so do with the water quality (79%). Many women have been reported to fetch water from distant places (0.5km to more than 1 km from their homesteads). The sensitivity matrix also shows that due to flooding, the most affected and vulnerable sector is the water quality[32].

Table 5.7: Households by sources of dinking water (Secondary data)

Tubewell	55.60%
Pond	0.20%
River	0.20%
Tap	43.40%
Dug well	0.30%
Canal	0.30%

Table 5.8: Satisfaction level of households by the water supply system and water quality (Primary data)

Name of service	Satisfactory	Moderately satisfactory	Unsatisfactory
Water supply	1%	35%	64%
Water quality	0%	21%	79%

5.4.7.2 Sanitation

Though majority of the people of the study area uses permanent latrines with septic tank (58.6%) or latrines with ring slab (28.4%), still there are a significant number of households using temporary latrines, that is, hanging (10.9%) and open pit (1.2%). Even a few people (1%) have no toilet at all. They use to use open places or bushes. All of the temporary latrines and open spaces are near the water body and remarkably, the outlets of the ring slab latrines are found to be in the surface water, which not only pollutes the water but also the surrounding environment. During the flood, the scenario becomes even worse when the river water overflow to the habitat area. Primary data shows that 76% is people are unsatisfied with the sanitation system of the area and not a single people is completely satisfied.

[32] See Table 5.2.1

Table 5.9: Households by sources of sanitation system (Secondary data)

Permanent with septic tank	58.6%
Ring slab	28.4%
Hanging	10.9%
Open pit	1.2%
No toilet	1%

Table 5.10: Satisfaction level of households by the sanitation system (Primary data)

Name of service	Satisfactory	Moderately satisfactory	Unsatisfactory
Sanitation	0%	24%	76%

5.4.7.3 Road

According to the FGD participants and in depth interviewees, there is lack of required number of roads. By direct observation, no road is found in good condition in the locality other than the main roads (primary roads). Due to lower level of road, people face serious trouble of water logging during the monsoon. It takes long, even 3 hours, to reach the CBD during the monsoon. Most of the roads constructed by the RHD in the study area are very low in elevation and also the quality is bad, so even with an hour raining, water is clogged there. It has been reported by the people during the in depth interview that, education is highly hampered due to water logging and bad communication during the monsoon period since students cannot go to school. Most of the people (73%) are unsatisfied with the existing access roads (internal communication roads) of the study area, only a very few (2%) is satisfied. But the condition of the main roads seems to be satisfactory by majority of the respondents.

Table 5.11: Satisfaction level of households by the road network and quality (Primary data)

Name of service	Satisfactory	Moderately satisfactory	Unsatisfactory
Access road	2%	27%	73%
Main road	63%	37%	0%

Poor condition of roads in the study area during pre monsoon and flooding period

5.4.7.4 Drainage

Drainage condition is found to be very poor in the study area. It is found by direct observation that there is lack of drainage system even in the secondary wide roads, and the situation is even worse in the internal roads. The existing drains are clogged with solid wastes. The natural drainage does not work due to illegal encroachment of wetlands. It is found in the study area that extensive development is going on encroaching the wetlands. Therefore, the natural drainage is highly in danger. Majority of the people of the study area (81%) is extremely unsatisfied with the drainage system. None is found to be fully satisfied with it.

Table 5.12: Satisfaction level of households by drainage system (Primary data)

Name of service	Satisfactory	Moderately satisfactory	Unsatisfactory
Drainage	0%	19%	81%

L-R: No drainage system in secondary road, clogged drain, encroachment of wetland.

5.4.8 Flood vulnerability: peoples' perception

According to the secondary data, the inhabitants of the study area self assessed their vulnerability status. It is found that majority of the households (74.3%) are severely vulnerable to flooding. 22.2% people claim them to be moderately vulnerable to flooding. A very few (3.5%) assess them to be non vulnerable.

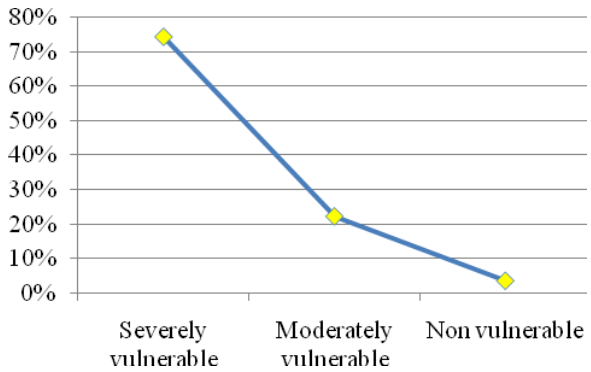


Figure 5.9: Degree of vulnerability of household during flood based on peoples' perception

However, the degree of vulnerabilty depends on the problems faced by them due to fooding and water clogging. Thses problems are of multifaceted like communication,water pollution, non availability of drinking water, crop damage, fish damage, homestaed damage, loss in income, loss of life including human being, livestock, poultry, water borne diseases, river eroson, sand/ silt deposition, lack of irrigation facilities and so on.Table 5.13 shows rankwise distribution of problems faced by the people of the study area and indicates the intensity of sufferimg as well as the vulnerabilty of households.

Table 5.13: Major problems faced by households during flood

Problems	Study area	
	Percentage	Rank
Water pollution	79.6	1
Communication	70.6	2
Household damage	58.2	3
Income loss	46.8	4
Lack of drinking water	42.8	5
Drainage congestion	34.9	6
Crop damage	23.4	7
Water brone diseases	20.8	8
River erosion	15.3	9
Fish damage	10.0	10
Sand/ silt deposition	8.8	11
Lack of irrigation facilities	7.5	12
Death of poultry and livestock	5.3	13
Death of human	0.5	14
Others	6.0	15
Not known	0.1	16

Table 5.13 shows water pollution to be the major problem faced by household during flood. It is also identified to be the most sensitive sector to flood by the sensitivity matrix[33]. Problems of communication, household damage, income loss are also dominating problems during the flooding as percieved by the people theselves.

5.4.8.1 Gender aspect of vulnerability

Generally, women and children are found to be the most vulnerable to flooding (Ikeda 1995; Paul 1997; Shahjahan 1998). During the in depth interviews and FGD, some reasons behind this vulnerability of the female group came out. Men are better connected to the early warning system since they use to work outside and have frequent access to the public spaces. On the other hand women are less mobilized outside their households. As vivid from the occupation[34], women are mostly relied on the poultry and livestock rearing and also on agriculture for their livelihood, which are highly affected by flooding. Moreover, they are considered to be the primary caregivers to the other family members. Therefore, without

[33] See 5.2
[34] See 5.4.3.1

considering own risk, they are supposed to protect their family at the first stake. These factors make women more vulnerable to flood.

5.4.9 Coping with flood: Communal and personal initiatives

People are generally resistant to changes; they tend to establish equilibrium to by directing resources to cope with the threatening hazards. Different groups of people have different ways to respond to these stresses. These adaptation strategies are influenced by various factors such as economic status, gender, age, intensity of flood and so on. During the FGD and in depth interviews, respondents have come up with the coping strategies they use to take during different levels of flooding.

Lower income group (comprising destitute, hard core poor and poor):

The worst sufferers are the low income group basically living in temporary structures. And most of them claimed not to receive any flood warning. They use to move to the roof top if there is a relatively flat roof, if situation goes even worse, they dismantle their house and reassemble in another place.

Lower middle income group:

This group usually has a semi permanent house. They are not willing to move to the relief camp leaving their house. They use to build 'make shift platform' inside their dwelling unit and keep moving it upward as the water level rise.

Middle income group:

This group resides in permanent housing. They use to build houses raising from the ground level to remain flood free. They use to create elevated pathway by putting bricks on the existing roads, but it can only be done when the water level is not high. Road level is raised by communal initiatives by putting brick chips, sands, construction wastes etc. since the municipality does not take any responsibility. Sometimes, if the road is completely inundated this group is found to even buy a boat for communication.

5.4.10 Analysis of adaptive capacity

The adaptive capacity is mostly observed as the household's or community's vulnerability (Few, 2003). It is basically an accumulated function of various factors which are mentioned in the above sections. The population distribution by sex shows near the half of the population is female which makes the group more vulnerable[35]. The major age group belongs to the working group, which increases the adaptive capacity. Majority of the people of the study area is dependent on business (trade) for their livelihood which is again very sensitive to flooding[36]. Therefore, adaptive capacity is lower in this sense. Still there is a significant number of illiterate people and people with poor educational background which is

[35] See 5.4.8.1
[36] See Table 5.2

also an indicator of the poor adaptive capacity. If the status of the existing infrastructural service is taken into account, it is found to be very poor and unsatisfactory, in general. All the people of the study area have same access to these infrastructures, so the adaptive capacity of the study area, in terms of infrastructural services and quality, is also considered to be very poor. Table 5.14 is formulated by taking the three dominating groups (percentage) in each category of the above surveyed factors for adaptive capacity.

Table 5.14: Adaptive capacity analysis

Group	Age	Occupation	Income per annum	Education	Existing infrastructure Service
Group A	69%	35%	36%	37%	Same
Group B	24%	23%	24%	22%	Same
Group C	7%	19%	19%	14%	Same

Table 5.14 shows that, either there is a dominating group bearing same status (i.e. age, education, occupation and income) or all of them have the same status (i.e. access to existing infrastructure).

The aim of the study is to analyze the vulnerability of the whole area (EFA) in order to assess the effectiveness of certain adaptation measures. The detailed vulnerability assessment of different groups within this area is out of the scope of this study and therefore, taking into account the dominant group in each considered factors for adaptive capacity and equal access to the existing infrastructure services, it can be assumed that the whole study population bears the same adaptive capacity.

5.5 Vulnerability Index

Vulnerability Index is the indication of the level of vulnerability for the hazards. Referring to the literature review 2.1*: Concept of vulnerability*, 'Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity'. Therefore, to calculate vulnerability index, all these three components are required. Adaptive capacity is considered to be the same for the whole study area and sensitivity and exposure data is gained from the respective indices. Table 5.15 shows the vulnerability index for each considered sectors. Vulnerability for each type of capital asset is calculated for each category of flooding, and then the vulnerability index per types of capital asset for flood in general for the study area, is calculated by making average of those.

Table 5.15: Vulnerability Index

Sectors	Types of capital asset	Riverine flood			Rainfall induced flood			Storm water flood			Vulnerability Index (Average)
		S.I.	E.I.	V.I.	S.I.	E.I.	V.I.	S.I.	E.I.	V.I.	
Ecosystem	Flora and fauna	60	0.89	***53.4***	60	0.78	***46.8***	60	0.44	***26.4***	**42.20**
	Water quality	93.33		***83.06***	93.33		***72.80***	93.33		***41.06***	**65.64**
	Air quality	53.33		***47.46***	53.33		***41.6***	53.33		***23.47***	**37.51**
	Soil contamination	46.67		***41.54***	46.67		***36.4***	46.67		***20.53***	**32.82**
Property , goods and services	Shelter/ Housing and other assets	60		***53.4***	60		***46.8***	60		***26.4***	**42.20**
	Infrastructure	86.67		***77.14***	86.67		***67.6***	86.67		***38.13***	**60.96**
Productive sectors/ livelihoods	Agriculture	66.67		***59.34***	66.67		***52***	66.67		***29.33***	**46.89**
	Trade	80		***71.2***	80		***62.4***	80		***35.2***	**56.27**
	Fisheries	40		***35.6***	40		***31.2***	40		***17.6***	**28.13**
Stakeholders/ livelihoods	Squatter and slum dwellers	80		***71.2***	80		***62.4***	80		***35.2***	**56.27**
	Land owners	40		***35.6***	40		***31.2***	40		***17.6***	**28.13**
	Tenants	26		***23.14***	26		***20.28***	26		***11.44***	**18.29**
	Agricultural workers	60		***53.4***	60		***46.8***	60		***26.4***	**42.20**
	Traders and businessmen	66.67		***59.34***	66.67		***52***	66.67		***29.33***	**46.89**

Notes: Vulnerability Index per sector for each hazard is calculated by multiplying Exposure Index (E.I) and Sensitivity Index (S.I). Average Vulnerability Index per sector is calculated by making average of all the vulnerability indices for specific sector to all the hazards. For example, the vulnerability Index for Flora and fauna to rainfall induced flood is (60X0.78) = **46.8**. And the average vulnerability index for Flora and fauna is (53.4+46.8+26.4)/3 = **42.20.**

The most vulnerable types of capital assets can be identified by table 5.16 where it is being ranked according to the vulnerability index.

Table 5.16: Ranking of vulnerable sectors

Rank	Types of capital assets	Category	Vulnerability Index (Scale 1 -100)
1	Water quality	***Natural***	**65.64**
2	Infrastructure	***Physical***	**60.96**
3	Trade	***Economical***	**56.27**
	Squatter and slum dwellers	***Social***	
4	Agriculture	***Economical***	**46.89**
	Traders and businessmen	***Social***	
5	Flora and fauna	***Natural***	**42.20**
	Shelter/ housing and other assets	***Physical***	
	Agricultural workers	***Social***	
6	Air quality	***Natural***	**37.51**
7	Soil contamination	***Natural***	**32.82**
8	Land owners	***Social***	**28.13**
	Fisheries	***Economical/ Natural***	
9	Tenants	***Social***	**18.29**

From table 5.16, it is vivid that, water quality is the most vulnerable sector in the Study area. Vulnerability of infrastructure and trade sector is also dominating the chart. For example, fisheries sector has a low index, since this loss is not a loss to the country in the sense that the fishes are not destroyed but released from the confines of ponds into the open water. And many people specially the poor, had an income opportunity from free open water fishing during the six to eight weeks of the flood.

5.6 Selection of potential adaptation options based on Vulnerability index

All the existing proposed adaptation options have been selected for assessment. Based on Vulnerability Index, two other options have been proposed from the case study bearing similar context. Enhancing emergency response mechanism is considered as one of the proposed option based on case study since the vulnerability index shows squatters and slum dwellers to be one of the most vulnerable sectors to flooding. Therefore, enhancing emergency response mechanism will be effective to reduce their vulnerability and also expected to significantly reduce the damage of assets. Enhancing early warning system has also been proposed as another measure. Agriculture is another sector identified to be highly vulnerable to flooding, therefore enhancing early warning system would be useful in this regard by changing the timing of sowing, which will in turn reduce the vulnerability of the agriculture workers as well.

The present status of early warning system in Dhaka is found to be significantly poor. The principal institution responsible for this is 'Flood Forecasting and Warning Center' (FFWC). FFWC does not have enough stations to measure the

river water level and is highly dependent on meteorological department for rainfall data. Moreover, the dissemination of flood warning is also very poor. There is lack of co ordination among the related institutions. This option is expected to be very useful for reducing the damage since during the in depth interviews, it is found that the people of the study area seem to have a good idea about what they would have done given an early warning.

The principal institution dealing with emergency response to flooding is 'Disaster Management Bureau'. It is found during the field visit, that their activity is very limited in Dhaka. It mostly focuses on the coastal area and on the areas subjected to flash floods. It does not even have any relief shelter in Dhaka city. School and other educational buildings are converted to flood shelter during the period of hazard which hampers the education system as well. Therefore, enhancing the emergency response mechanism is highly needed for Dhaka, specifically for Dhaka East. This can be started with community based management program where the initial cost is much lower.

5.7 Criteria identification

In order to perform an adaptation (measures) assessment, criteria should be identified. These main aspects and criteria have been selected in a participatory manner based on stakeholders' assessment. Key stakeholders for the study area are considered for this research covering public and private sectors and also community representatives from different groups i.e. business, agriculture etc. Focus group discussion has been conducted with the stakeholder group in order to identify the most important aspects and criteria to be considered during adaptation assessment. The main aspects were identified as criteria category. Prior FGD, each representative has been asked to prepare a set of criteria according to their own perspective. This was done to avoid potential bias during the discussion. The criteria (Table 5.17) are finalized as a consensus from the FGD. The objectives of the finalized criteria are also decided from the FGD, for example, the criterion 'Cost' has to be minimized while the criterion 'Vulnerability reduction' has to be maximized.

Table 5.17: List of selected criteria

Category of Criteria	Criteria	Units	Objective
Vulnerability	Vulnerability reduction	Percentage	Max
Financial	Cost	Millions	Min
Environmental	Enhancement of ecological condition	"1-5"	Max
Socio political	Public and political acceptance	"1-5"	Max
Macro economical	Employment generation	"1-5"	Max
Socio-economical	Achievement of MDG	"1-5"	Max
Institutional & Technological	Institutional and technical capacity	"1-5"	Min

Table 5.18: Explanation of criteria

Criteria	Explanation	Comments
Vulnerability reduction	Reduction of vulnerability through the implementation of the adaptation measures	The higher the score, the higher the degree of vulnerability reduction
Cost	Direct costs for the implementation and maintenance of the adaptation measure	Higher score refers to lower cost
Enhancement of ecological condition	Adaptation measure will enhance the ecological condition	Higher score stands for higher degree of enhancement of ecological condition
Public and political acceptance	Public and political acceptance for the adaptation measure	Higher score stands for higher level of acceptance
Employment generation	Employment generated through the implementation of the adaptation measure	Higher score refers to higher employment generation
Achievement of MDG	Level of achievement of MDG by the implementation of adaptation measure	Higher score refers to higher level of achievement
Institutional and technical capacity	Institutional and technical capacity required to implement the adaptation measure	Higher score refers to lower capacity requirement

5.8 Scoring of criteria per adaptation option

Scoring of each adaptation option based on the criteria is done by the selected experts. The criterion 'Cost' against each adaptation option has been put based on the secondary data. Since the selected experts have expertise in different fields related to flooding and all of them have experience working on the study area, it is expected that their point of view for scoring has covered the major concerns which should be considered during assessing adaptation options in the studied context. Table 5.19 has been formulated by making average of scores given by the experts for each option against specific criterion.

Table 5.19: Scoring of adaptation option

Adaptation Options			Criteria						
			Vulnerability reduction (in percentage)	Cost (US $ in millions)	Enhancement of ecological condition (Scale of 1 to 5)	Public & political acceptance (Scale of 1 to 5)	Employment generation (Scale of 1 to 5)	Achievement of MDG (Scale of 1 to 5)	Institutional and technical capacity (Scale of 1 to 5)
Existing	*Structural measures*	Construction and up gradation of storm sewer/ drainage system	**80**	**- 64.27**	**3**	**4**	**4**	**4**	**-5**
		Raised road	**65**	**- 4.07**	**2**	**4**	**3**	**3**	**-4**
		Embankment	**70**	**-19.94**	**2**	**5**	**4**	**3**	**-4**
		Flood wall	**60**	**-5.78**	**2**	**3**	**3**	**3**	**-3**
		Canal Improvement	**80**	**-13.74**	**5**	**2**	**3**	**4**	**-4**
	Non structural measures	Protection of water retention areas	**75**	**-0.54**	**5**	**2**	**4**	**4**	**-2**
Proposed	*Non structural measures*	Enhancing emergency response mechanism	**60**	**-0.75**	**1**	**4**	**2**	**4**	**-2**
		Enhancing early warning system	**85**	**-2.05**	**3**	**5**	**1**	**5**	**-4**

Note:
Question for scoring: How does the mentioned adaptation option will affect specific criteria?
Scoring scale of 1 to 5: 1 stands for lowest positive effect and 5 stands for highest positive effect.

5.9 Standardization of scores

Table 5.19 uses different scales and units to score the criteria, i.e. percentage, millions, numeric scale of 1-5. Therefore, all the scores are being standardized to a common scale. Table 5.20 shows all the standardized scores. Here the scale of '0 to 1' has been used for standardization. For example, the criteria 'Employment generation' uses a 1 to 5 scale.

1 ⟶ 5 (Observed scale)
0 ⟶ 1 (Standardized scale)

The standardization process is different for those which do not have the standardization scale and observed scale in the same direction, for example, 'cost' criterion. For this, a higher score is less desirable than a lower score. The cost criterion is scored in absolute value not by scale. From table 5.19, the highest cost is 64.27 million and the lowest is 0.75 million. So, the scale is from 0.75 to 64.27. In this standardization process, it has to be ensured that costs closer to 0.75 million get a higher score and costs closer to 64.27 million get lower score.

64.27 ⟵ 0.75 (Observed scale)
0 ⟵ 1 (Standardized scale)

Table 5.20: Standardized scores

Adaptation options	*Vul. Reduc.*	*Cost*	*Enhan. of ecological condition*	*Public & political accep.*	*Employ. generation*	*Achiev. of MDG*	*Inst. and technical capacity*
Construction and up gradation of storm sewer/ drainage system	**0.8**	**0.0**	**0.5**	**0.7**	**1.0**	**0.5**	**0.0**
Raised road	**0.2**	**0.9**	**0.3**	**0.7**	**0.7**	**0.0**	**0.3**
Embankment	**0.4**	**0.7**	**0.3**	**1.0**	**1.0**	**0.0**	**0.3**
Flood wall	**0.0**	**0.9**	**0.3**	**0.3**	**0.7**	**0.0**	**0.7**
Canal Improvement	**0.8**	**0.8**	**0.8**	**0.7**	**0.7**	**0.5**	**0.3**
Protection of water retention areas	**0.6**	**1.0**	**1.0**	**0.0**	**1.0**	**0.5**	**1.0**
Enhancing emergency response mechanism	**0.0**	**1.0**	**0.0**	**0.7**	**0.3**	**0.5**	**1.0**
Early warning system	**1.0**	**1.0**	**0.5**	**1.0**	**0.0**	**1.0**	**0.3**

The standardization of scores and all calculations have been performed with the aid of the excel based MCA tool, MAPA - DST developed by IHS.

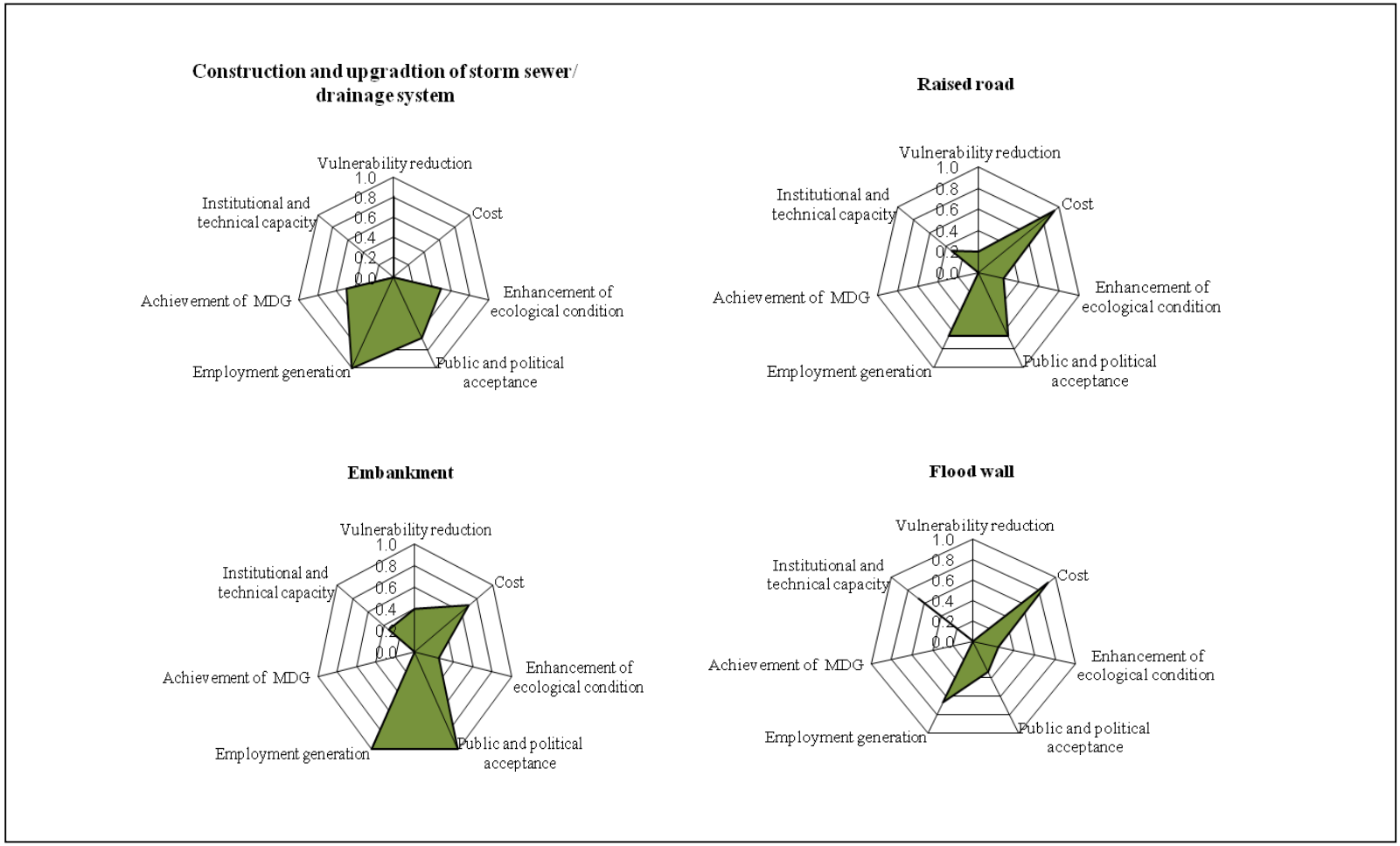


Figure 5.10(a): Standardized scores for each adaptation option against selected multiple criteria

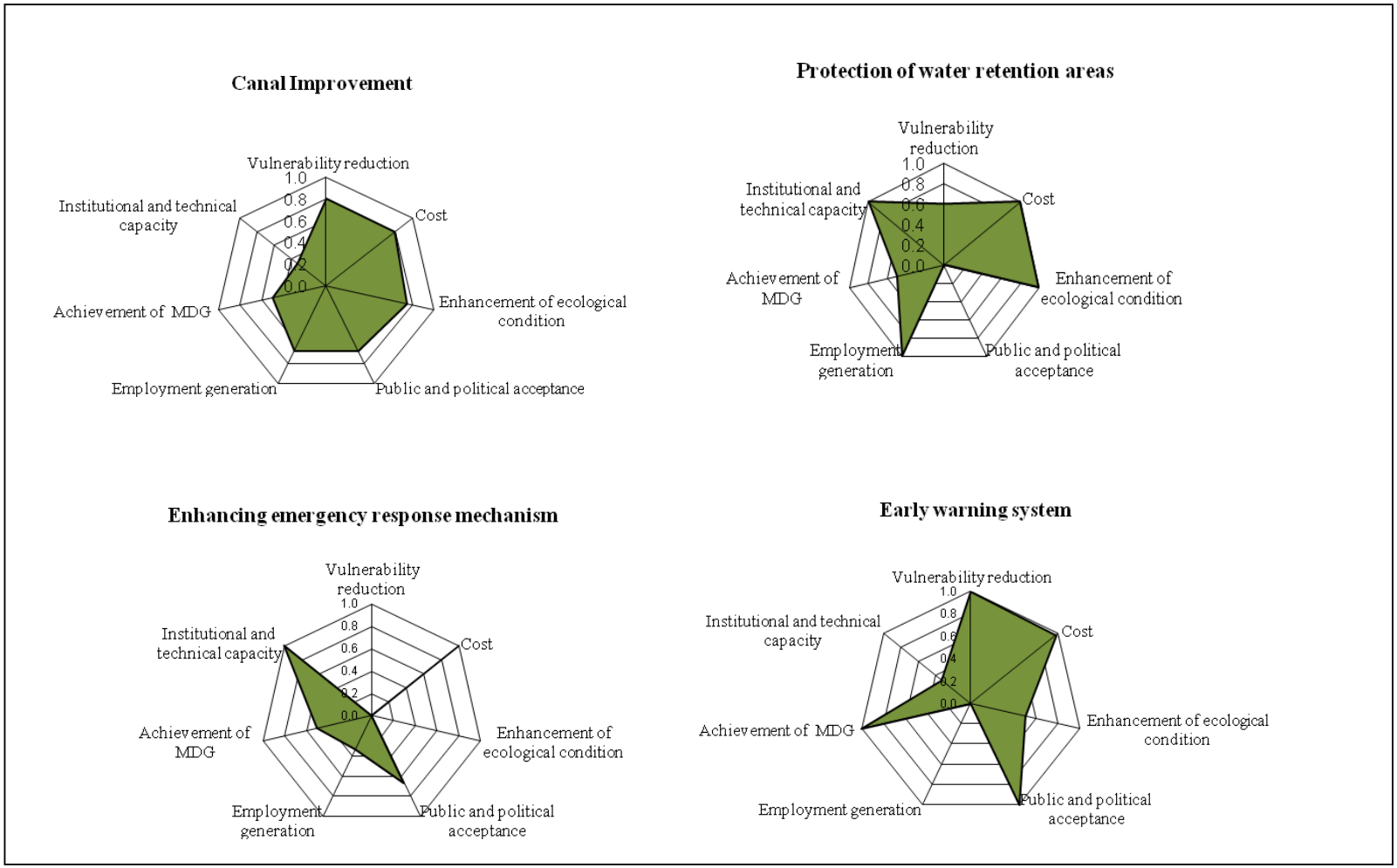


Figure 5.10 (b): Standardized scores for each adaptation option against selected multiple criteria

Figure 5.10 (a), (b) is a visual way to see how each adaptation option performs on specific criterion according to the experts' opinion.

5.10 Prioritization of adaptation options based on equal weights for criteria

Adaptation options are prioritized considering all the criteria of equal weight. The scores given by the experts are combined with the weight (which is considered here to be equal) to get the weighted score. This is based on the following formula: $WS_{ij} = W_i * S_j$, where W_i stands for weight of criterion i, S_j stands for score of option j for criteria i.

Table 5.21: Score for equal weights

Final Score	Options	Vul. Reduc.	Cost	Enhan. of ecological condition	Public & political accep.	Employ. generation	Achiev. of MDG	Inst. and tech. capacity
	Weights	**14.3%**	**14.3%**	**14.3%**	**14.3%**	**14.3%**	**14.3%**	**14.3%**
0.50	Construction and up gradation of storm sewer/ drainage system	0.11	0.00	0.07	0.10	0.14	0.07	0.00
0.44	Raised road	0.03	0.13	0.04	0.10	0.10	0.00	0.05
0.53	Embankment	0.06	0.10	0.04	0.14	0.14	0.00	0.05
0.40	Flood wall	0.00	0.13	0.04	0.05	0.10	0.00	0.10
0.64	Canal Improvement	0.11	0.11	0.11	0.10	0.10	0.07	0.05
0.73	Protection of water retention areas	0.09	0.14	0.14	0.00	0.14	0.07	0.14
0.50	Enhancing emergency response mechanism	0.00	0.14	0.00	0.10	0.05	0.07	0.14
0.69	Enhancing early warning system	0.14	0.14	0.07	0.14	0.00	0.14	0.05

Then prioritization of adaptation options based on equal weights (Table 5.22) is done with the final weighted scores per option considering equal weights. The formula of the weighted summation is: $FS_i = \sum WS_{ij}$

Table 5.22: Prioritization of adaptation options based on equal weights

Options	Score	Rank
Protection of water retention areas	0.73	1
Enhancing early warning system	0.69	2
Canal improvement	0.64	3
Embankment	0.53	4
Construction and up gradation of storm sewer/ drainage system	0.50	5
Enhancing emergency response mechanism	0.50	6
Raised road	0.44	7
Flood wall	0.40	8

Table 5.22 shows that with the equal weights of criteria, protection of water retention areas is the most effective option and flood wall is resulted to the least effective one.

5.11 Weighting of criteria

Weighting of each selected criterion is done based on another focus group discussion with the same stakeholder group. It ensures the inclusion of stakeholders' preferences in the adaptation assessment process. The idea behind the FGD-2 was to determine the degree of relative importance of each criterion on the basis of the scored table by experts (Table 5.19). They have been given the table before the FGD to weigh the criteria according to individual perspective. This was done to avoid bias during the FGD. Table 5.23 shows the outcome (consensus) of the FGD-2. An interesting outcome of the FGD-2 was the very low weighting of the criterion 'Achievement of MDG', which shows the major concern of the stakeholders to deal with the basic livelihood of the people of the study area and also lack of awareness of the community representatives about the national development issues.

Table 5.23 Weighted criteria

Category of Criterion	Criterion	Impact Range	Units	Importance	Values	Weights
Vulnerability	Vulnerability reduction	25	Percentage	Very High	100	22.7%
Financial	Cost	63.73	Millions	High	80	18.2%
Environmental	Enhancement of ecological condition	4	"1-5"	High	70	15.9%
Socio political	Public and political acceptance	3	"1-5"	Moderate	60	13.6%
Macro economic	Employment generation	3	"1-5"	Moderate	60	13.6%
Socio-economic	Achievement of MDG	2	"1-5"	Low	30	6.8%
Institutional & Technological	Institutional and technical capacity	3	"1-5"	Low	40	9.1%

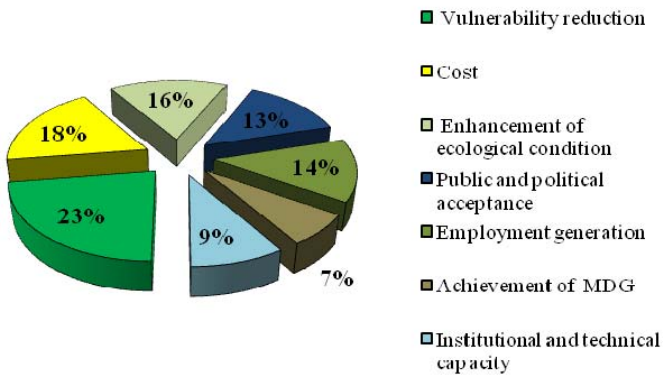


Figure 5.11: Criteria weights

Table 5.23 also shows the impact range of each criterion based on the range between highest and lowest score for each criterion. For example, the criterion 'vulnerability reduction' has '85' as highest score and '60' as lowest score. So, the impact range for 'vulnerability reduction' is (85 - 60), that is, 25. Within the same importance level, there were two different degrees (values), from which one has to be selected. This is done as the outcome (consensus) of FGD-2. The final weight of each criterion is based on the importance and value data decided by the stakeholder group. The formula for estimating the criteria weights is:

$$W_i = V_i / \sum V,$$

where W_i stands for weight of criterion i, V_i stands for importance value assigned by stakeholders to the criterion i.

5.11.1 Weighted scores

The scores given by the experts are combined with the weights decided by the stakeholders in order to get the weighted scores. This is based on the same formula used for table 5.21.

Table 5.24: Weighted score

Final Score	Options	Vul. Reduc.	Cost	Enhanc. of ecological condition	Public & political accep.	Employ. Gen.	Achiev. of MDG	Inst. and tech. capacity
	Weights	***22.7%***	***18.2%***	***15.9%***	***13.6%***	***13.6%***	***6.8%***	***9.1%***
0.52	Construction and up gradation of storm sewer/ drainage system	0.18	0.00	0.08	0.09	0.14	0.03	0.00
0.47	Raised road	0.05	0.17	0.04	0.09	0.09	0.00	0.03
0.56	Embankment	0.09	0.13	0.04	0.14	0.14	0.00	0.03
0.40	Flood wall	0.00	0.17	0.04	0.05	0.09	0.00	0.06
0.69	Canal Improvement	0.18	0.14	0.12	0.09	0.09	0.03	0.03
0.74	Protection of water retention areas	0.14	0.18	0.16	0.00	0.14	0.03	0.09
0.44	Enhancing emergency response mechanism	0.00	0.18	0.00	0.09	0.05	0.03	0.09
0.72	Enhancing early warning system	0.23	0.18	0.08	0.14	0.00	0.07	0.03

It is vivid from the table that 'Protection of water retention areas' has the highest score, while 'Flood wall' has the lowest.

5.12 Prioritization of adaptation options

Prioritization of adaptation options is done based on the final weighted scores per option (Table 5.24). The formula of the weighted summation is same as used for table 5.22.

Table 5.25: Prioritization of adaptation options

Options	Score	Rank
Protection of water retention areas	0.74	1
Enhancing early warning system	0.72	2
Canal Improvement	0.69	3
Embankment	0.56	4
Construction and up gradation of storm sewer/drainage system	0.52	5
Raised road	0.47	6
Enhancing emergency response mechanism	0.44	7
Flood wall	0.40	8

From the table 5.25, it is vivid that the top three priority for adaptation options are protection of water retention areas, enhancing early warning system and canal improvement. Comparing to the ranking with equal weights, there is no significant change in ranking, only change is shuffle between raised road and enhancing emergency response mechanism.

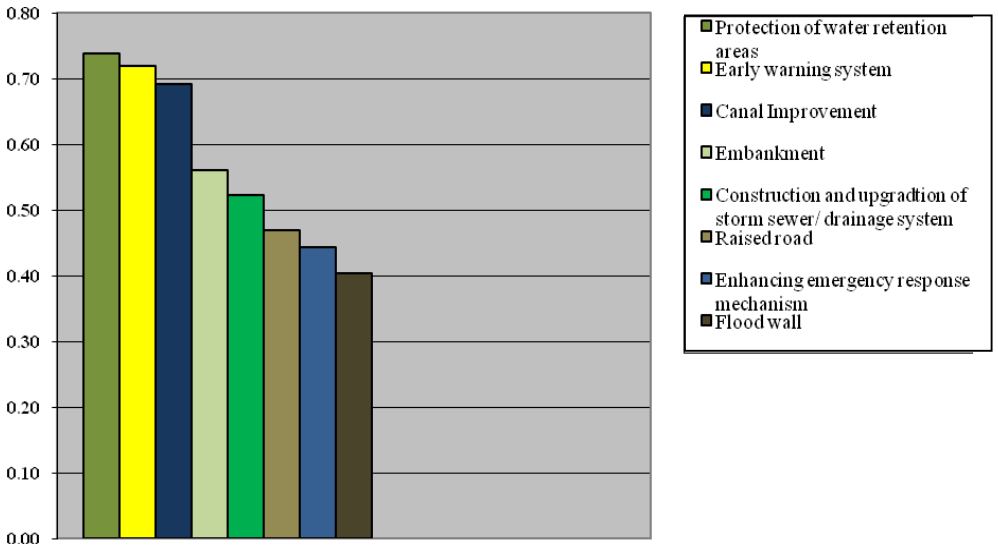


Figure 5.12: Ranking of adaptation options

5.13 Sensitivity Analysis

Sensitivity analysis is conducted to investigate how sensitive the result is to the variables (criteria weights). It is found that by changing one criterion weight slightly and keeping the rest as they are, there is no significant change in the ranking (see annex 10a).

There are small changes if one criterion weight is changed drastically keeping the others same. But again, if the options are categorized in broad three groups (the first five options in two groups and the last three in one group), according to the original ranking with the weighted criteria there is no change in the ranking of the groups, only change is shuffle of ranking in between the group itself.

In the example below, the importance level for criterion 'Achievement of MDG' has been radically changed to low from high. And also the value have been changed to low (30) from quite a high value (80).The ranking with this changed weight (Table 5.27) shows that there is only a shuffle of ranking between the first two options, the rests remain same as before (for more option analyses, see annex 10b).

Table 5.26: Sensitivity analysis (changing variable)

Category of Criteria	Criteria	Impact Range	Units	Importance	Values	Weights
Vulnerability	Vulnerability reduction	25	Percentage	Very High	100	20.4%
Financial	Cost	63.73	Millions	High	80	16.3%
Environmental	Enhancement of ecological condition	4	"1-5"	High	70	14.3%
Socio political	Public and political acceptance	3	"1-5"	Moderate	60	12.2%
Macro economic	Employment generation	3	"1-5"	Moderate	60	12.2%
Socio-economic	Achievement of MDG	2	"1-5"	High *(Low*)*	80 *(30**)*	16.3%
Technological	Institutional and technical capacity	10	"1-5"	Low	40	8.2%

Table 5.27: Sensitivity analysis (ranking with changed variable)

Adaptation options	Score	Rank
Early warning system	0.75	1
Protection of water retention areas	0.71	2
Canal Improvement	0.67	3
Construction and up gradation of drainage system	0.52	4
Embankment	0.50	5
Enhancing emergency response mechanism	0.45	6
Raised road	0.42	7
Flood wall	0.36	8

Therefore, it can be concluded that the results are quite robust with regard to the criteria weights. Sensitivity analysis is a way to incorporate the uncertainty and range of stakeholders' preferences.

5.14 Summary

There are basically three focal points for the research findings for adaptation assessment- vulnerability, criteria for assessment and prioritization of adaptation options. Impacts of different types of flooding hazard have been investigated to identify the vulnerability of affected sectors. It is found that water quality is the most vulnerable sector of the study area. Infrastructure, trade and agriculture are also extremely vulnerable to flooding. More on that, squatters and slum dwellers' livelihood are found to be highly affected. These vulnerability indices have helped to select the adaptation options. All the exisitng proposed adaptation options have been undertaken for assessment and based on the vulnerability index, two more adaptation options have been proposed for assessment selected from case studies with relevant context. Multiple criteria were selected to assess those options as consensus by the key stakeholders of the study area through a focus group discussion. Based on those criteria, experts on relevant fields scored each adaptation options. After the experts' scoring, the same stakeholder group weighted each criteria (consensus) according to the degree of importance by a focus group discussion. The experts' scoring have been combined with criteria weights to get the final scores for each adaptation options. The prioritization of the adaptation options is based on the final score. It is found that 'Protection of water retention area' is the most effective option to be undertaken to reduce the vulnerability of the EFA to flooding. 'Enhancing early warning system' and 'Canal improvement' are also identified to be very effective options, then comes consecutively embankment, construction and up gradation of storm sewer/ drainage system, raised road, enhancing emergency response mechanism and flood wall. By performing sensitivity analysis, it is found that the result is somewhat robust to the deviations of criteria weights.

Chapter 6: Conclusion

This last chapter of thesis presents the conclusive remarks for the whole study along with answering the research questions. Interpretation of the results is presented here as well. After interpreting the results, contribution of the research is drawn. Lessons learnt from the study are also brought into light by focusing on the adaptation process, assessment and also the ground reality at the governmental level. In the last part of this chapter, it puts forward the scope for further research.

6.1 Answers to the research questions

The study objectives are to investigate the vulnerability of Eastern fringe area to flooding, the adaptation assessment and prioritization of options. In the process, an understanding has been developed about the impacts of different flooding hazards in the study area. The assessment process takes into account relevant key stakeholders' opinions as well as experts' judgments. Moreover, at the last part of the research findings, sensitivity analysis has been performed to test the robustness of the results and incorporate stakeholders' preference uncertainty.

6.1.1 Answer to the research sub question 1

Q. Which are the most vulnerable types of capital assets in the Eastern fringe of Dhaka?

To answer this question, vulnerability assessment of relevant sectors was needed to be conducted. It has been learnt from reviewing literature that, vulnerability is a collective outcome of exposure, sensitivity and adaptive capacity. Therefore, in order to assess the vulnerability of Dhaka EFA, above mentioned factors are assessed for the study context.

- ***Exposure index*** for the study area has been prepared considering the factors like duration, frequency, spatial extent for different types of flood based on secondary data. The result shows the study area is most exposed to riverine flood.

- ***Sensitivity index*** is identified based on the study on the previous floods from last few decades and their impacts on specific types of capital assets. Each type of capital asset has been scored according to the impacts of different categories of flood. The result showed that water quality is the most sensitive capital asset to flooding. The next two sensitive capital assets are infrastructure and trade.

- ***Adaptive capacity*** is analyzed for the whole study area itself. It was out of the scope of the study to do in depth adaptive capacity analysis for each neighborhood. In order to perform the analysis of adaptive capacity, relevant factors which influence the adaptive capacity (i.e. education, income level, age, existing infrastructure services) have been analyzed as a whole for the study area. The analysis resulted that either there is a dominating group (i.e. Age, education, occupation and

income) or all of them have the same status (i.e. access to existing infrastructure).The prioritized options will be subjected for the whole EFA itself. Therefore, the adaptive capacity is considered to be the same for the whole study area.

- ***Vulnerability index*** resulted from the above mentioned exposure index, sensitivity index and adaptive capacity analysis, which shows the most vulnerable types of capital assets to flooding for EFA. Table 6.1 shows the outcome of the vulnerability assessment which answers research sub question 1 by illustrating the level of vulnerability of different types of capital assets of EFA. This assessment also answers the research objective of investigating the vulnerability of the study area to flooding.

Table 6.1: Answer to research sub question 1

Rank	Types of capital assets	Category	Vulnerability Index (Scale 1 -100)
1	Water quality	*Natural*	**65.64**
2	Infrastructure	*Physical*	**60.96**
3	Trade	*Economical*	**56.27**
	Squatter and slum dwellers	*Social*	
4	Agriculture	*Economical*	**46.89**
	Traders and businessmen	*Social*	
5	Flora and fauna	*Natural*	**42.20**
	Shelter/ housing and other assets	*Physical*	
	Agricultural workers	*Social*	
6	Air quality	*Natural*	**37.51**
7	Soil contamination	*Natural*	**32.82**
8	Land owners	*Social*	**28.13**
	Fisheries	*Economical/ Natural*	
9	Tenants	*Social*	**18.29**

6.1.2 Answer to the research sub question 2

Q. What are the initiatives and measures taken by the Government to reduce the vulnerability of the Eastern fringe to flooding?

To answer the question, it was needed to do in depth study about the activities of different relevant organizations dealing with flood management in Dhaka. These organizations include both public sector (Government) and private sectors employed by public sector (NGOs, consultant firms) for flood management of the study area.

It is found that no significant measure has been undertaken to reduce the vulnerability of the study area to flooding. After the catastrophic flood of 1988, Government of Bangladesh in collaboration with JICA conducted an in depth survey on Dhaka East and came up with certain adaptation options to protect the

area from flooding. A hundred year standard of protection is adopted by this proposal. Feasibility study of the proposal has been conducted 1996 and revision of that has been done in 2006.

The proposed measures includes construction of flood embankment, pumping stations, regulators/ sluices, flood walls, construction and upgrading road network, protection of retention basins and canal improvement.

Though it has been declared as priority project by successive governments, the proposed measures are still not implemented.

6.1.3 Answer to the research sub question 3

Q. Which are the main aspects and criteria to consider during the assessment of available adaptation options?

To answer this question, a focus group discussion was conducted with the key stakeholders of the study area comprising of representatives from communities, business and agriculture sector, relevant government organizations and NGO. The idea behind the FGD was to select the most important criteria to assess adaptation options in a participatory manner.

The main aspects to be considered during the assessment of adaptation options are decided as criteria categories by the stakeholders, these are vulnerability, financial, environmental, socio political, macro economic, socio economic, institutional and technological aspects. The criteria resulted from the discussion under these aspects are vulnerability reduction, cost, enhancement of ecological condition, pubic and political acceptance, employment generation, achievement of MDG, institutional and technical capacity.

According to the stakeholder group, the above mentioned criteria and aspects are the most important to be considered during the assessment of adaptation options and it was finalized as consensus. The objectives for the criteria are also decided by FGD. The objectives for the criteria 'cost' and 'institutional and technical capacity' is to minimize them whereas for the rest is to maximize them.

6.1.4 Answer to the main research question

Q. What are the most effective adaptation measures against flooding for the Eastern fringe of Dhaka?

The most effective adaptation options are identified based on the experts' judgments (scores) and criteria weights decided by the stakeholders group. Experts have scored each adaptation option against specific criteria and the selected criteria have been weighted by the same stakeholder group after the scoring. The experts' scores are combined with weights of the criteria and resulted to the final score. Based on this final score for each adaptation option, the ranking of adaptation options is done. Thus the primary objective of the study, to assess and prioritize most effective adaptation measures against flooding for EFA, is also

fulfilled and it answered the main research question as well. From the following table showing the ranking, it is vivid that protection of water retention area is the most effective option against flooding for the study area considering the existing constraints i.e. cost, required institutional and technical capacity. By the most effective and highly prioritized options it is meant that these options meet most of the criteria to a certain extent.

Adaptation options	Rank
Protection of water retention areas	1
Enhancing early warning system	2
Canal Improvement	3
Embankment	4
Construction and up gradation of storm sewer/ drainage system	5
Raised road	6
Enhancing emergency response mechanism	7
Flood wall	8

Sensitivity analysis is conducted to test the robustness of the results to the criteria weights. And it is found that the ranking of adaptation options is quite robust to the deviations of criteria weights which means a certain degree of stakeholders' uncertainty is also incorporated.

6.2 Interpretation of results

The outcome for the vulnerability assessment is the identification of the most vulnerable types of capital assets to flooding. This is the primary activity to perform in order to select adaptation options. To reduce the vulnerability of the identified sectors, appropriate measures would be selected. Vulnerability is an aggregated outcome of exposure, sensitivity and adaptive capacity, that is, how exposed the area is to specific types of flooding, how sensitive each sector is to flooding and last but not the least the capacity of the people to adapt to these hazards. Water quality is identified to be the most vulnerable sector; infrastructure and trade are also extremely vulnerable. Livelihood of squatters and slum dwellers are under high risk to flooding, it determines their low adaptive capacity and high exposure and sensitivity to flooding. Therefore, measures should be taken to protect these sectors on the first hand.

The main aspects and list of criteria to be considered during the adaptation assessment process is a significant finding of the research which is done by stakeholders' direct involvement. These were resulted from their discussion which limits the risk of institutional or personal bias. Seven main aspects are being distinguished as criteria categories including vulnerability, financial, environmental, socio political, macro economic, socio-economic, institutional and technological. The objectives of the criteria are identified by the stakeholders as well, like which are needed to be strengthened, i.e. cost, institutional and technical capacity. Since the stakeholder group includes representatives from different groups from community, governmental and non governmental organizations, the identified criteria accumulates quite a wide range of perceptions of different categories of people.

The adaptation assessment method applied here, is an integrated one since it includes experts' judgment and stakeholders' preferences, and also it links vulnerability assessment to adaptation assessment. The whole process of prioritization allows a gradual approach to the goal providing a structured utilization of stakeholders' preferences. Based on the stakeholders' preferences, vulnerability reduction, cost, enhancement of ecological condition, public and political acceptance, employment generation are elicited to be most significant criteria, while achievement of MDG, institutional and technical capacity performed as less significant. This was also an interesting outcome, since there is a global attention for achieving MDG for the least developed countries, but the stakeholders of the study area are not in line with that. This was basically for the fact that flood hazard poses serious risk to the livelihood itself of the people of the study area. Therefore, the stakeholders are more concern for saving that rather than being concern about the national and global issues. But at the same time, the community representatives are not that much aware of the MDG as well. Thus, this interactive weighting method has been proved to be a facilitative tool for the elicitation of stakeholders' preferences. In addition, the exchange of information based on different perspectives of the stakeholders made the outcome of the decision making more legitimate and defensible.

The final outcome of the research is the ranking of the adaptation options. The provision of effective prioritization (ranking) is a challenging goal. This prioritization process permits co application of the two approaches, technical expertise (experts' judgment) and normative judgment (stakeholders' preferences). It is based on both subjective (experts' judgment) and objective (actual cost) information. The ranking shows protection of water retention area, enhancing early warning system and canal improvement to be the most effective. This is quite interesting, since the construction and up gradation of drainage system is being most talked about in the flood management sector of Dhaka for reducing flood vulnerability. But it is proved to be a quite less prioritized measure. Apparently if drainage system is improved, it is expected to reduce flooding. But for a least developed country there are other factors to be considered as well. Construction and up gradation of the drainage system requires quite high budget and also high technical capacity which is less available in the context. So, in relative importance along with the existing constraints, protection of water retention area proved to be most effective option for the study area for reducing vulnerability to flooding.

Sensitivity analysis of the result in relation with the criteria weight (variable) shows that the result is quite robust with regard to the criteria weights**.** Thus, to a certain extent uncertainty of stakeholders' preferences is also incorporated by sensitivity analysis.

6.3 Contribution of the research

The most vulnerable types of capital assets of the study area to flooding are identified by the research. It can assist policymakers in formulating sectoral policies by notifying the most vulnerable sectors of the study area. Moreover, the result presents a list of vulnerable sectors, so it is convenient to incorporate related sectors in an integrated policy framework. It will be helpful for the decision makers to take sound and balanced decisions in the governmental level by having a notification about the vulnerable assets and also about the priority sectors for decision making.

The adaptation assessment procedure for flooding of the study area would be benefitted as because the most important criteria to be considered during the assessment and also their importance level are identified by the research. This is based on stakeholders' preferences. Thus stakeholders' preferences will come into light in front of the decision makers. The stakeholder group includes even the root level representatives (i.e. farmer, business group) of the study area whose preferences are often neglected during the decision making process. The need of some criteria to be strengthened is illustrated as well, for example, the required institutional and technical capacity for the implementation of the adaptation measures should be strengthen, so do the cost. This is a notification for the decision makers to put more emphasis on those criteria.

The prioritization of adaptation options for the study area, would work as a decision support for both the decision makers and the policy makers. There are measures already proposed for the study area, but it is difficult to implement all those at the same time. The prioritization thus will help to take decision on the implementation of the most immediate (high priority) measures to be undertaken. Moreover, 'Enhancing early warning system', a proposed measure from relevant case study, has shown up to be one of the most effective measures to be undertaken for the study area considering the limitation of cost and institutional and technical capacity. This can be a valuable contribution for the flood management of the study area. It is worth to mention, the whole process of including these two groups (experts and stakeholders) builds the platform for knowledge generation which is also a productive side of the research.

The methodology adapted for the research itself can be useful for the researchers to take it as an example of how MCA can be applied for flood management incorporating vulnerability and adaptation assessment in a structured way. This methodology is potential to ensure transparency and multidimensionality by considering multiple criteria and multiple stakeholders' preferences.

Last but not the least, the problem of vulnerability of Dhaka East to flooding, that is addressed by this research itself is a crucial concern these days in Bangladesh. There are proposed adaptation measures as well to reduce the vulnerability but not yet being implemented because of lack of budget and other constraints. It is not possible to implement all the measures at the same time. Therefore, by addressing this problem and prioritizing the adaptation measures, the research has contributed to the easy and fast implementation of the measures for reducing the vulnerability of the EFA.

6.4 Lessons learnt

There is a wide variety of options for adaptation to reduce vulnerability to flooding. There comes the need for assessing those adaptation options. Several methods are there to perform this task. These tools help to screen the most effective adaptation appropriate for specific context. Thus, those provide us with the information of which options should be implemented. Elicitation of stakeholders' preferences is vital here in order to get a reliable and defensive outcome.

It should also be kept in mind that, those who are the end users (people) should not depend on the environmental researchers to find out all the solutions for them, since there is always uncertainty. So, at the end of the day, it is upon the end users, how they behave and make decisions in everyday life considering the impacts of climate change. Only then the information that the researchers are producing can be used in the most adequate way.

Documentation of successful adaptation to flooding all over the world can be very useful for addressing the issue, since it is always beneficial to learn about the adaptation to current climate variability.

It has been realized during the exercise of vulnerability assessment, that all the population is not vulnerable to flooding in the same way. The poor are expected to be the worst sufferer due to climate variability. Therefore, the correlation between vulnerability and poverty shows the demand of highlighting poverty alleviation in the climate change policies.

The poor existing structure of the governmental organizations urges the need to check whether they can handle the challenges for the implementation of the proposed measures. Fine tuning between different relevant government and private organizations and also with the stakeholders is a precondition for the successful execution of the proposed measures.

The local governments and ministries of the least developed countries are not giving much attention to the climate change issues since they are suppressed with the demand of other basic issues of poverty, basic infrastructural services, education, housing, health etc. To expand the intrusion of climate change in the policy level and government plans, it is needed to be seen as a support for enhancing the MDG achievement. It is also because of the fact that, if the deficiencies of development cannot be tackled, there is no actual base for adaptation. But for a least developed country like Bangladesh, where there is high political instability with a poor economic base, this is quite difficult to conceive.

6.5 Scope for further research

For meticulous application, the frameworks for both vulnerability and adaptation assessment stated in the study requires considerable research. For example, the likely impacts for each adaptation option can be generated by different projects to get reliable and specific data which can be based on different parameters, i.e. diverse aspects of flooding, adaptation details, neighborhood context. That is, an in depth ex ante impact assessment can be done. And again different judgment can be gained on the basis of different perspectives, i.e. experts, different groups of people from the considered area (business, agriculture, squatters etc), government. The assessment can be more in depth considering the temporal scales as well, i.e. short term, medium term, long term. Moreover, it can be tested further on criteria weighting, such as using other means of assigning weights, investigating different methods for the aggregation of criteria etc. A larger sample of stakeholders can be taken undertaken to map their preferences.

An adaptation option to be undertaken is not a discrete decision, nor based on reducing vulnerability to certain climatic hazard alone. The other considered factors for the studied context can be limited budget, limited institutional and technical capacity, facts of land reclamation for the implementation of the option and so on. The outcome of the evaluation can again be rectified by various methods other than sensitivity analysis, i.e. cost effectiveness analysis.

Climate change poses multifaceted risks to flooding which may not be possible to take into account only by MCA method. These are likely to be undertaken by the broader decision making process i.e. risk management. Though MCA can provide with the information of relative merits of the assessed adaptation options, but it is not the single tool for selecting adaptation options for flooding. It can be a part of this assessment process along with other needed measures. It is because of the fact that flooding is a sensitive sector aggravated by climate change, which is mentioned earlier to have a wide range of risks. Therefore, how and where risk management can fit in this assessment process can be a scope for further study as well.

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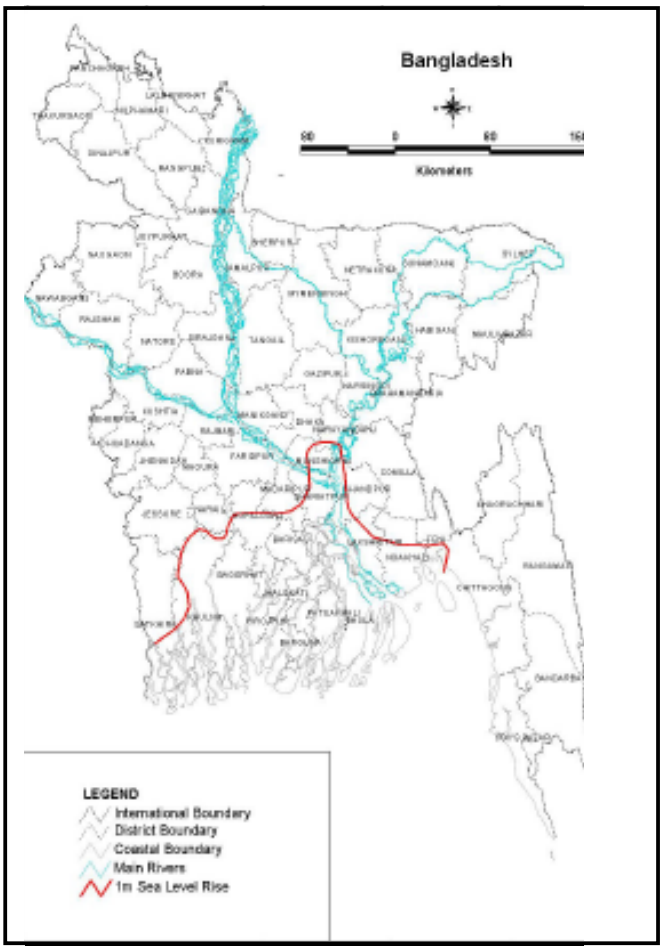
Annexes

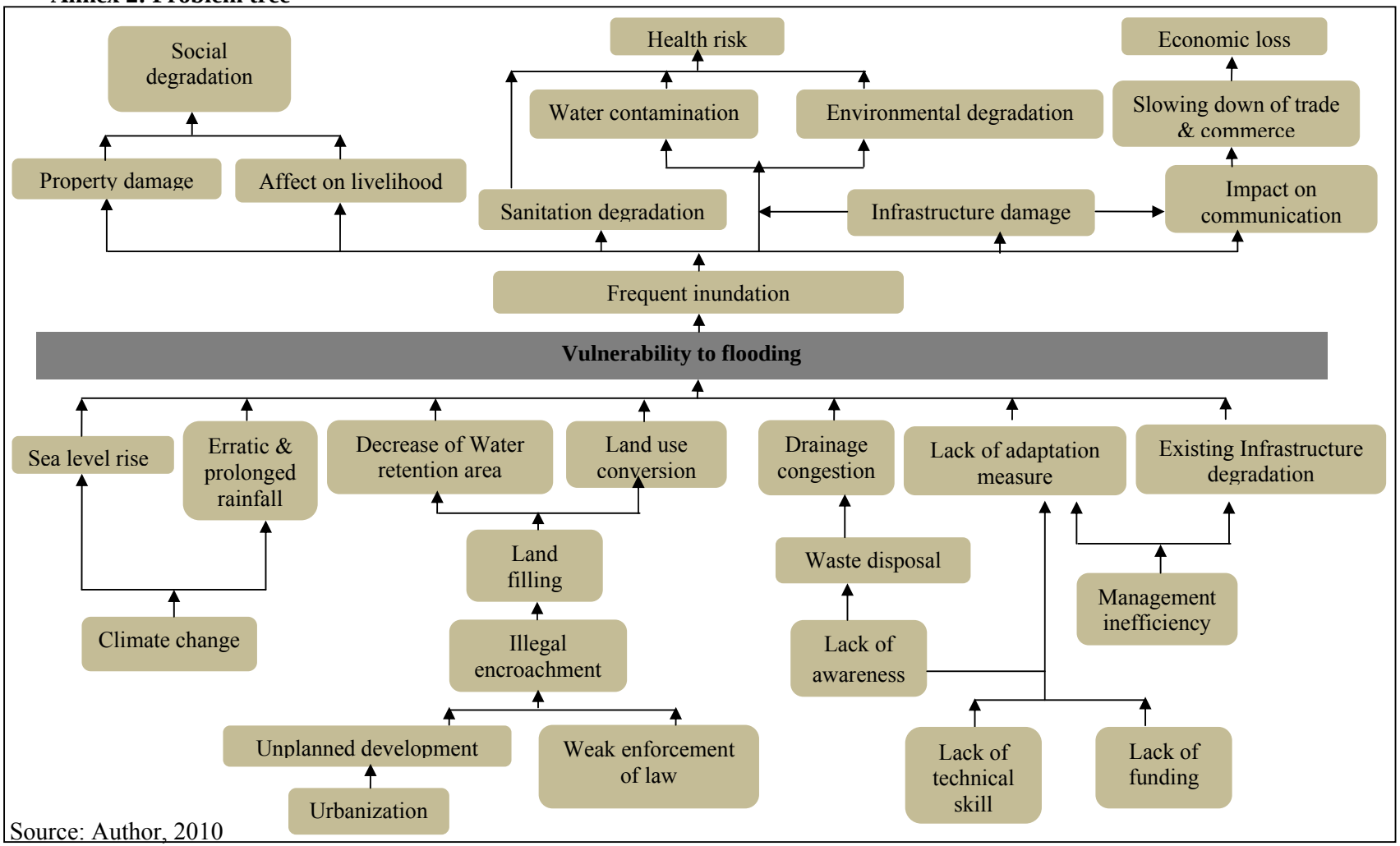
Annex 1: *Coastline intrusion*

Figure: Coastline intrusion to the inland of Dhaka with sea level rise by 2050



Source:
http://www2.kankyo.metro.tokyo.jp/c40/c40tokyo/pdf/keynoteLecture_symposium/dl_mallick.pdf

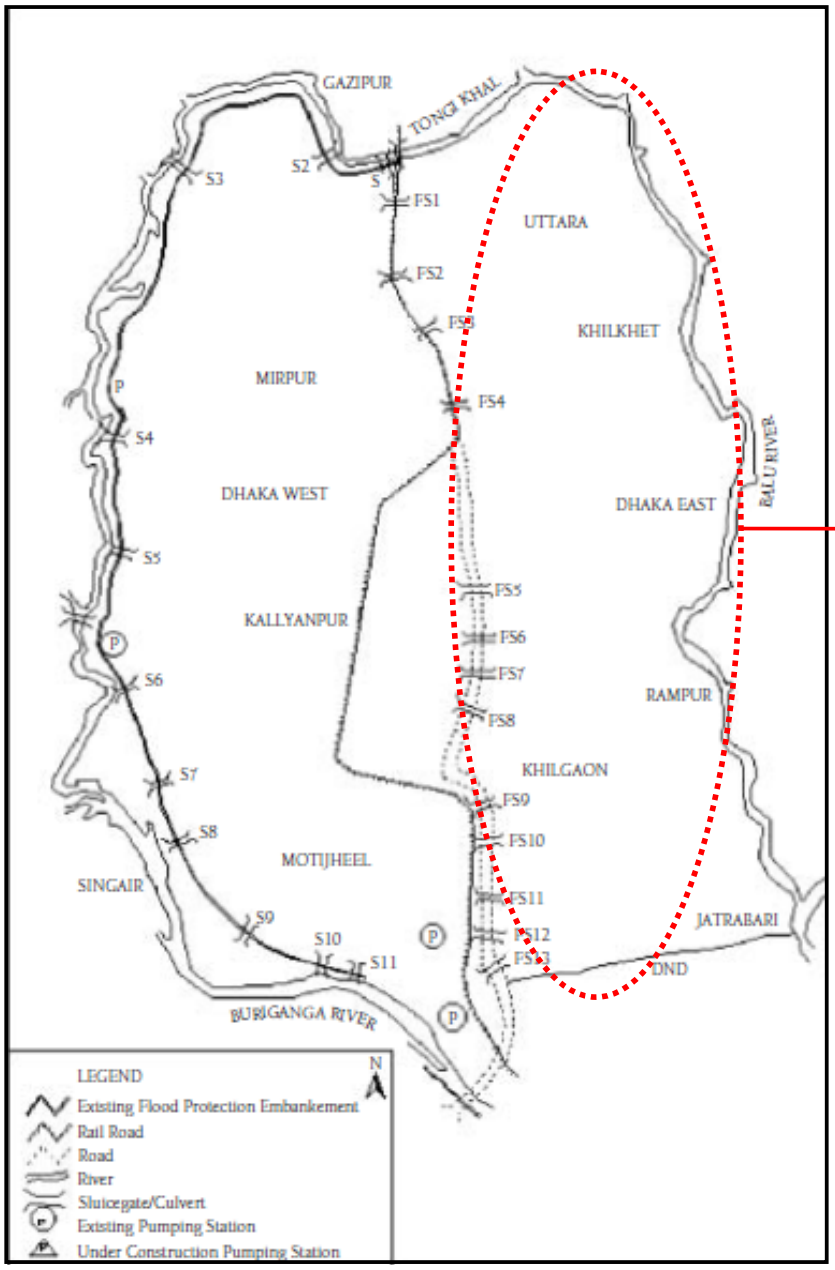
Annex 2: Problem tree



Source: Author, 2010

Annex 3: ***Existing flood control infrastructure of Dhaka***

Figure: Existing flood control and drainage infrastructure of Dhaka, showing unprotected Dhaka East



Source: eds. Nishat, 1999

Annex 4: *Time scale*

The first draft research proposal was submitted on mid February and the second draft on 21st June. The field work was scheduled after this submission in the month of July. At the end of August, the first draft for the final thesis was completed and the final submission is scheduled in mid September. In all the possible phases, an additional time for revision has been considered within the time frame. The time scale for the whole research period is shown in the table below.

Table: Research schedule

Sl.	Task	Month (2010)							
		Feb.	Mar.	April	May	June	July	Aug.	Sept.
1.	Proposal finalizing								
2.	Building Theoretical framework								
3.	Available secondary data collection								
4.	Research design								
5.	Research instruments design								
6.	Finalizing first three chapters								
7.	Field work								
8.	Data analysis and conclusion								

Legend:

-Acquired time -Time for revision

Fieldwork schedule:

Research field work was conducted for a period of 5 weeks. The field work schedule is shown in the table below.

Table: Field work schedule

Sl.	Task	July 2010				Augus t2010	Tools
		1st week	2nd week	3rd week	4th week	1st week	
1.	Vulnerability assessment						Questionnaire survey and Secondary data
	-Impact study						
	-Adaptive capacity analysis						
	-Exposure & sensitivity Index -Calculation of Vulnerability index						
2.	Revision of adaptation options and Experts' judgment						In depth Interview
3.	Stakeholders' assessment						Focus group discussion
4.	Revision of collected data						

Legend:

-Acquired time

Annex 5: *Research Variables and Indicators*

From the research sub questions mentioned in Chapter 1, variables and indicators are formulated to guide data collection works.

Table: Research variables and indicators

Sl.	Research sub-question	Variables	Indicators	Sub indicators	Data sources	Linkage with the research methodology	
1.	What are the impacts of flooding in the Eastern fringe?	Vulnerability	Exposure index	Frequency of hazard	Secondary data	Exposure assess.	Vul. Assess.
				Spatial extent of hazard			
				Duration of hazard			
2.	Which are the most vulnerable types of capital assets in the Eastern fringe of Dhaka?		Sensitivity index	Impacts on Natural assets		Sensitivity assess.	
				Impacts on Physical assets			
				Impacts on Economical assets			
				Impacts on Social assets			
			Adaptive capacity index	Social aspect	Secondary data, direct observ.	Adaptive capacity asses.	
				Available technology			
				Infrastructure			
3.	What are the measures and initiatives taken by government and other stakeholders to reduce the vulnerability of the Eastern fringe?	Governance Instruments	Partnership agreements		Secondary data gained from desk research	Selection of potential adaptation options	
			Investment program for infrastructure improvement				
			Special committee for climate change adaptation				
			Emergency response mechanism				
			Early warning system				
			Employment				

			of laws and regulations in terms of land use pattern			
		Financial and Economic initiatives	Calamity fund allocation			
		Project planning	Extension of existing protective measures			
			Establish. of infrastructure to protect Eastern fringe from flooding			
4.	Which are the main aspects and criteria to consider during the assessment of available adaptation options?	Criterion	Vulnerability reduction		Secondary data, FGD and direct observ.	Selection of criteria for assessment of adaptation options
			Cost			
			Level of institutional and technical capacity			
			Level of public and political acceptance			
			Level of achievement of MDG			
			No. of jobs generated			
			Level of enhancement of ecological condition			

Notes:

Explanation sub indicators for sensitivity index:

See ***Annex 6***

Explanation of Adaptive capacity indicator:

Social aspect: It refers to vulnerability experienced by people and their social systems i.e. income level of the inhabitants, education etc.

Annex 6*: Considered impacts of flooding on ecosystem*

Water quality	
Surface water	Changes in PH level
	Changes in the amount of Dissolved Oxygen
	Changes in biological Oxygen demand (Presence of dead cells, bacteria and other biological pollutants)
	Presence of Chlorides, solids, dissolved solids, turbidity
	Presence of any type of coliform
Drinking water	Contamination of surface water through any of the above means
	Contamination of the ground water
	Contamination due to infrastructure damage
Flora and fauna	
Deterioration of water quality	
Long term inundation in polluted stagnant flood water	
Soil contamination	
Soil quality	
Long term inundation in polluted stagnant flood water	
Soil erosion	
Contamination through rotten wastes	
Air quality	
Bad odour from logged water, human excreta and other types of waste	
Increase of physical and chemical pollutants	
Agro biodiversity	
Same as Flora and fauna	

Source: Author, 2010

Annex 7: *Considered property goods and services*

Table: Shelter/ housing typology in the research area

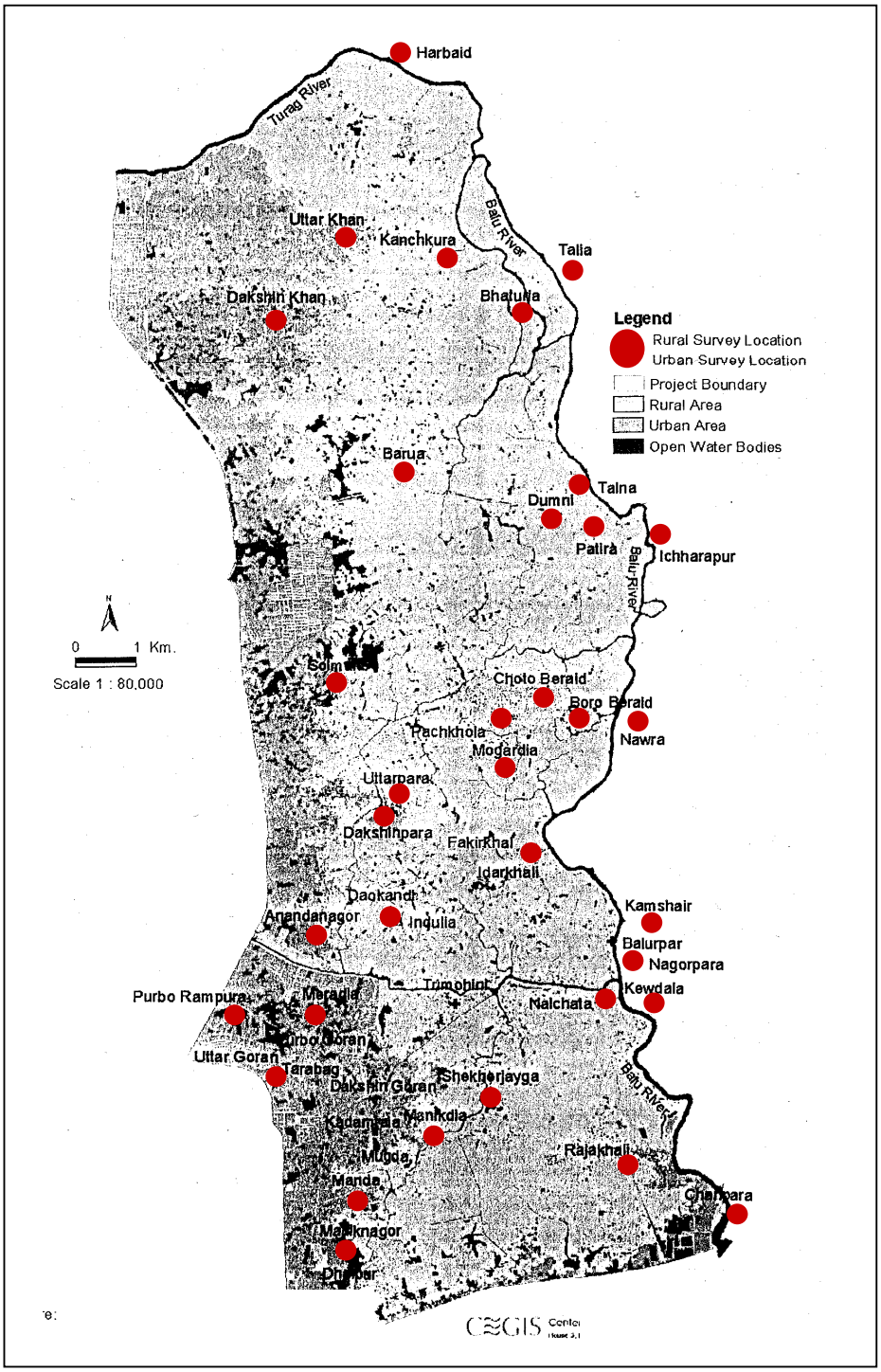
Type	Life span	Roof	Wall	Floor
Type 1: Permanent housing	50 years	Concrete	Brick	Cement
Type 2: Semi permanent housing	20 years	C.I/ Tile/ Wood	Brick	Cement
Type 3: Katcha 1	15 years	C.I/ Tile/ Wood	C.I	Cement
Katcha 2		C.I/ Tile/ Wood	Bamboo	Mud/ bamboo/ wood
Katcha 3		C.I/ Tile	Mud	Mud/ bamboo/ wood
Type 4: Katcha 4	5 years	Thatch/ straw/ bamboo	Mud	Mud/ bamboo/ wood
Type 5: Temporary	1 year or less	Thatch/ leaves/waste material, polythene	mud	Mud/ debris/ polythene

Source: eds. Nishat, 1999

Considered infrastructure systems: Water supply, sanitation, transportation network, electricity .

Annex 8: *Social survey location*

Figure: Social survey location for secondary data



Source: Halcrow Group, 2006

Annex 9: ***Questionnaire for primary data collection***

Questionnaire survey

Research Title: CLIMATE CHANGE ADAPTATION ASSESSMENT: A CASE OF THE EASTERN FRINGE OF DHAKA, BANGLADESH

(Survey data will be used for academic purpose only)

Location and identification of household	
Date of interview	
Name of Interviewer	
Name of respondent	
Address	

A. Socio Economic characteristics of household

Sl. No.	Name of household member	Age	Sex	Education*	Occupation* (Principal)	Annual income*

***Coding instruction:**

Education	Illiterate
	Able to read and write only
	Primary (Class I to V)
	Secondary (Class VI-X)
	Higher Secondary
	Graduate
	Masters
Occupation	Farmer
	Business
	Service
	Contractual
	No occupation
	Others

Annual income	<=$169
	$170-$365
	$366-$859
	$860-$1539
	$1540-$3429
	>=$3430

B. **Status of infrastructural service**	
i. Water	_____
ii. Drainage	_____
iii. Sanitation	_____
iv. Access road	_____
v. Main road	_____

***Coding instruction:**
Score 1 to 3 according to satisfaction level
Satisfactory = 1; Moderately satisfactory = 2; Unsatisfactory = 3

Annex 10: ***Sensitivity analysis***

10(a). Slightly change in variable (importance and values for one criterion): ***Option 01, 02, 03***

Note: The highlighted boxes show the changes
* The original criterion importance
**The original criteria value

Option 01:

Category of Criteria	Criteria	Impact Range	Units	Importance	Values	Weights
Vulnerability	Vulnerability reduction	25	Percentage	Very High	100	22.2%
Financial	Cost	63.73	Millions	Very High *(High*)*	90 *(80**)*	20.0%
Environmental	Enhancement of ecological condition	4	"1-5"	High	70	15.6%
Socio political	Public and political acceptance	3	"1-5"	Moderate	60	13.3%
Macro economic	Employment generation	3	"1-5"	Moderate	60	13.3%
Socio-economic	Achievement of MDG	2	"1-5"	Low	30	6.7%
Technological	Institutional and technical capacity	10	"1-5"	Low	40	8.9%

Adaptation options	Score	Rank
Protection of water retention areas	0.74	1
Early warning system	0.72	2
Canal Improvement	0.69	3
Embankment	0.56	4
Construction and up gradation of drainage system	0.51	5
Raised road	0.48	6
Enhancing emergency response mechanism	0.45	7
Flood wall	0.42	8

Option 02:

Category of Criteria	Criteria	Impact Range	Units	Importance	Values	Weights
Vulnerability	Vulnerability reduction	25	Percentage	Very High	100	21.7%
Financial	Cost	63.73	Millions	High	80	17.4%
Environmental	Enhancement of ecological condition	4	"1-5"	Very High *(High*)*	90 *(70**)*	19.6%
Socio political	Public and political acceptance	3	"1-5"	Moderate	60	13.0%
Macro economic	Employment generation	3	"1-5"	Moderate	60	13.0%
Socio-economic	Achievement of MDG	2	"1-5"	Low	30	6.5%
Technological	Institutional and technical capacity	10	"1-5"	Low	40	8.7%

Adaptation options	Score	Rank
Protection of water retention areas	0.75	1
Early warning system	0.71	2
Canal Improvement	0.69	3
Embankment	0.55	4
Construction and up gradation of drainage system	0.52	5
Raised road	0.46	6
Enhancing emergency response mechanism	0.42	7
Flood wall	0.40	8

Option 03:

Category of Criteria	Criteria	Impact Range	Units	Importance	Values	Weights
Vulnerability	ulnerability reduction	25	Percentage	Very High	100	23.8%
Financial	Cost	63.73	Millions	High	80	19.0%
Environmental	nhancement of ecological condition	4	"1-5"	High	70	16.7%
Socio political	Public and political acceptance	3	"1-5"	Low (Moderate*)	40 *(60**)*	9.5%
Macro economic	Employment generation	3	"1-5"	Moderate	60	14.3%
Socio-economic	Achievement of MDG	2	"1-5"	Low	30	7.1%
Technological	Institutional and technical capacity	10	"1-5"	Low	40	9.5%

Adaptation options	Score	Rank
Protection of water retention areas	0.77	1
Early warning system	0.71	2
Canal Improvement	0.69	3
Embankment	0.54	4
Construction and up gradation of drainage system	0.52	5
Raised road	0.46	6
Enhancing emergency response mechanism	0.43	7
Flood wall	0.41	8

10b. Drastic change in variable (importance and values for one criterion):
Option 04, 05

Option 04:

Category of Criteria	Criteria	Impact Range	Units	Importance	Values	Weights
Vulnerability	Vulnerability reduction	25	Percentage	Very High	100	21.3%
Financial	Cost	63.73	Millions	High	80	17.0%
Environmental	Enhancement of ecological condition	4	"1-5"	High	70	14.9%
Socio political	Public and political acceptance	3	"1-5"	Moderate	60	12.8%
Macro economic	Employment generation	3	"1-5"	Very High *(Moderate*)*	90 *(60**)*	19.1%
Socio-economic	Achievement of MDG	2	"1-5"	Low	30	6.4%
Technological	Institutional and technical capacity	10	"1-5"	Low	40	8.5%

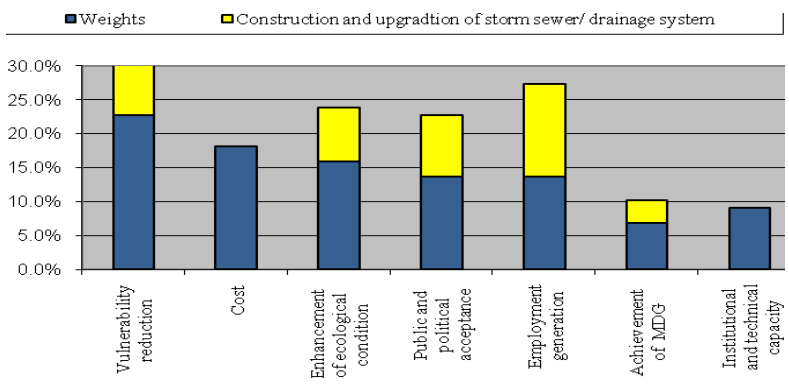
Adaptation options	Score	Rank
Protection of water retention areas	0.76	1
Canal Improvement	0.69	2
Early warning system	0.67	3
Embankment	0.59	4
Construction and up gradation of drainage system	0.55	5
Raised road	0.48	6
Enhancing emergency response mechanism	0.44	7
Flood wall	0.42	8

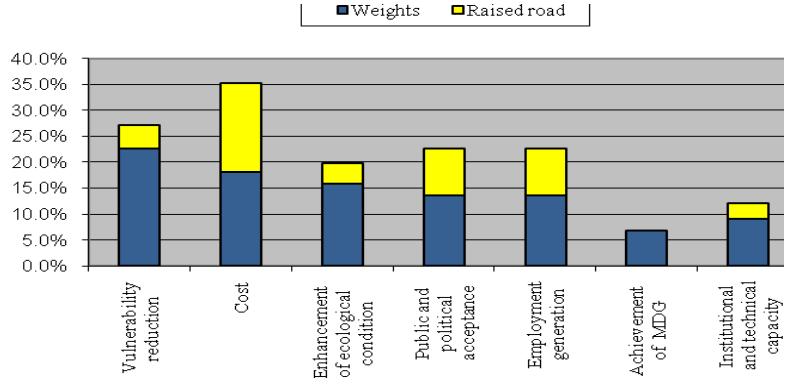
Option 05:

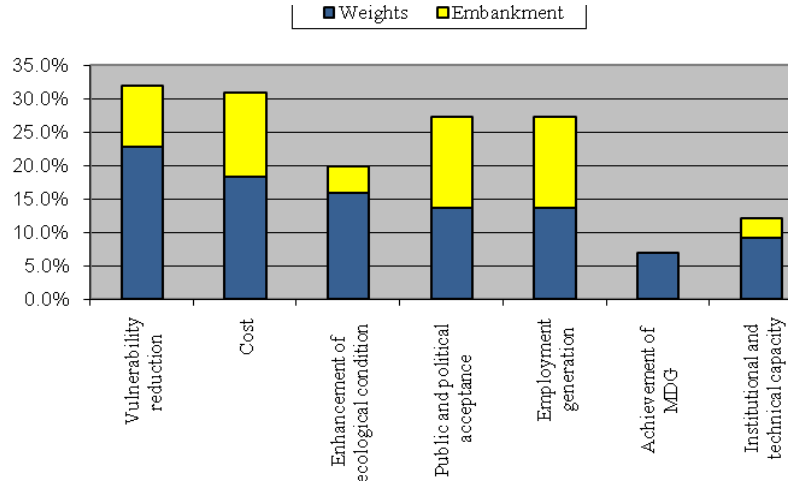
Category of Criteria	Criteria	Impact Range	Units	Importance	Values	Weights
Vulnerability	Vulnerability reduction	25	Percentage	Very High	100	20.4%
Financial	Cost	63.73	Millions	High	80	16.3%
Environmental	Enhancement of ecological condition	4	"1-5"	High	70	14.3%
Socio political	Public and political acceptance	3	"1-5"	Moderate	60	12.2%
Macro economic	Employment generation	3	"1-5"	Moderate	60	12.2%
Socio-economic	Achievement of MDG	2	"1-5"	Low	30	6.1%
Technological	Institutional and technical capacity	10	"1-5"	High *(Low*)*	70 *(40**)*	18.4%

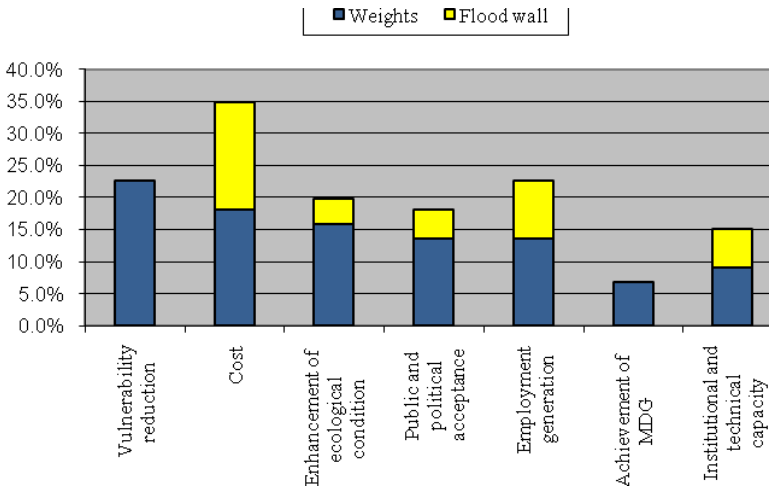
Adaptation options	Score	Rank
Protection of water retention areas	0.76	1
Early warning system	0.69	2
Canal Improvement	0.67	3
Embankment	0.55	4
Construction and up gradation of drainage system	0.49	6
Enhancing emergency response mechanism	0.48	5
Raised road	0.46	7
Flood wall	0.42	8

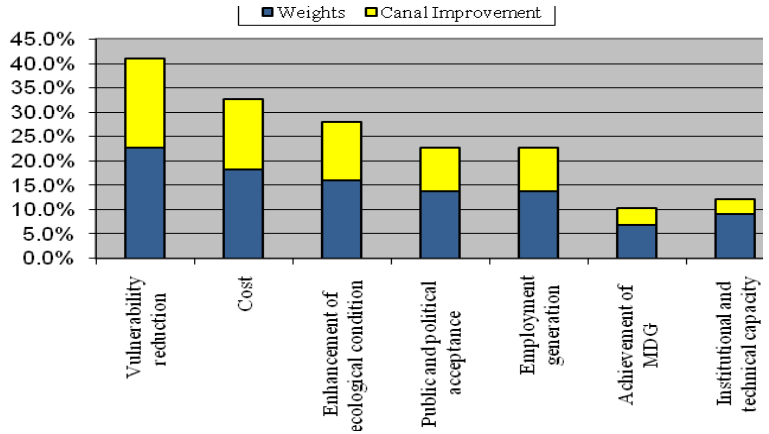
Annex 11: *Adaptation options' scores and weights*

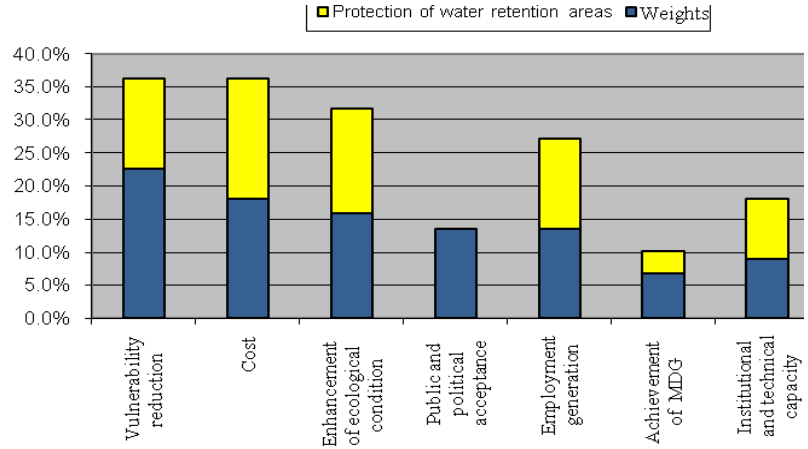


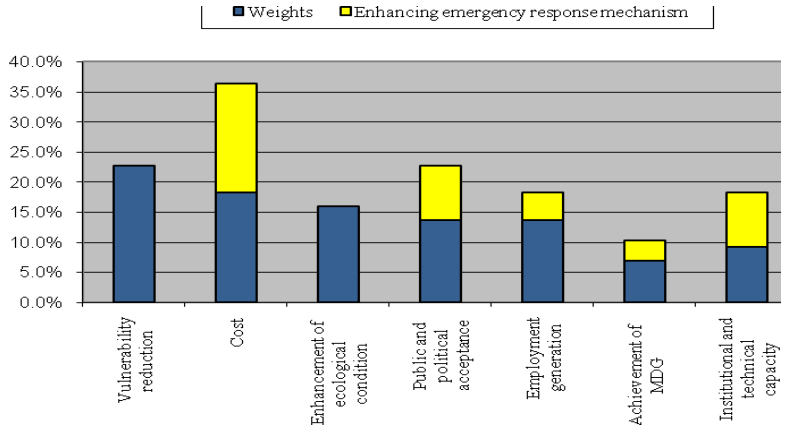


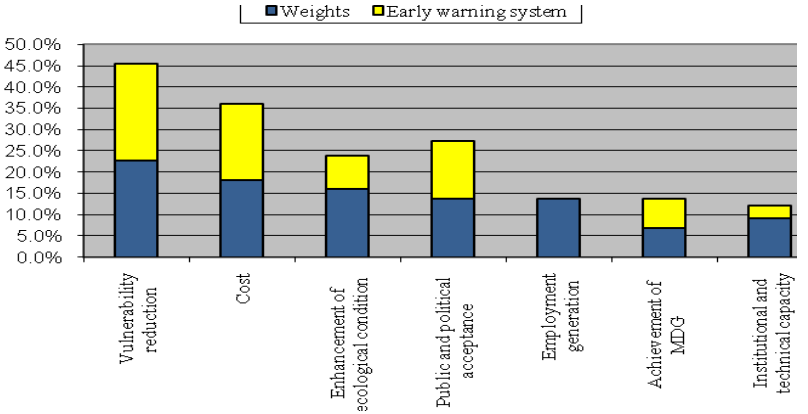





Weights
Canal Improvement
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Vulnerability reduction
Cost
Enhancement of ecological condition
Public and political acceptance
Employment generation
Achievement of MDG
Institutional and technical capacity


Protection of water retention areas
Weights
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Vulnerability reduction
Cost
Enhancement of ecological condition
Public and political acceptance
Employment generation
Achievement of MDG
Institutional and technical capacity


Weights
Enhancing emergency response mechanism
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Vulnerability reduction
Cost
Enhancement of ecological condition
Public and political acceptance
Employment generation
Achievement of MDG
Institutional and technical capacity


Weights
Early warning system
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Vulnerability reduction
Cost
Enhancement of ecological condition
Public and political acceptance
Employment generation
Achievement of MDG
Institutional and technical capacity