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Assessment of adaptation measures against flooding in the city of Dhaka, Bangladesh

By Anika Nasra Haque, Stelios Grafakos and Marijk Huijsman

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Abstract

Dhaka is one of the world's largest megacities with a high rate of urbanization. Due to the setting of greater Dhaka in a deltaic plain, it is extremely prone to detrimental flooding. Risks associated with flood are expected to increase in the coming years because of the global climate change impacts as well as the high rate of urbanization the city is facing. The low lying part of Dhaka (Dhaka East) faces most severe risk of flooding. Traditionally, this part has been efficiently storing the excess water caused by excessive rainfall and the canals connected to the rivers gradually drained the water to the rivers. But the alarmingly increasing population of Dhaka is leading towards the encroachment of these water retention areas because of the land scarcity. The natural drainage for the city is not performing well and the area is still unprotected from flooding, which causes major threats to its inhabitants. This situation increases the urgency to effectively adapt to current floods caused by climate variability and to the impacts of future climate changes. The government is planning several adaptive measures to protect the area whereas a systematic framework to analyze and assess them is lacking. The objective of the paper is to develop an integrated framework for the assessment of various (current and potential) adaptation measures aimed at protecting vulnerable areas from flooding. The study firstly assesses current and future risks from flooding in the most sensitive region of the city. Subsequently, the study identifies, analyses and assesses adaptive initiatives and measures to address flood risks in the Eastern fringe area. Adaptation assessment is conducted within the framework of Multi Criteria Analysis methodology which allows both normative judgment and technical expertise in the assessment process. Based on the assessment and analysis, adaptive measures are prioritized to enable more effective action. Such a participatory integrated assessment of adaptation options is a new approach in flood management in least developed countries and in Bangladesh in particular. A framework for prioritization of adaptation measures is lacking in the decision making process in Bangladesh which could immensely assist in informed and structured decisions while developing adaptation strategies.

Keywords: *Climate change, Adaptation assessment, Flood and vulnerability, Prioritization, Multi Criteria Analysis, Dhaka*

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Introduction

It has been projected that despite of the effort to lessen greenhouse 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. 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 greenhouse 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). 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 world's 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.

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 variability's 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). Flooding has become a regular event in Dhaka not only by the overflow of river but also through water clogging.

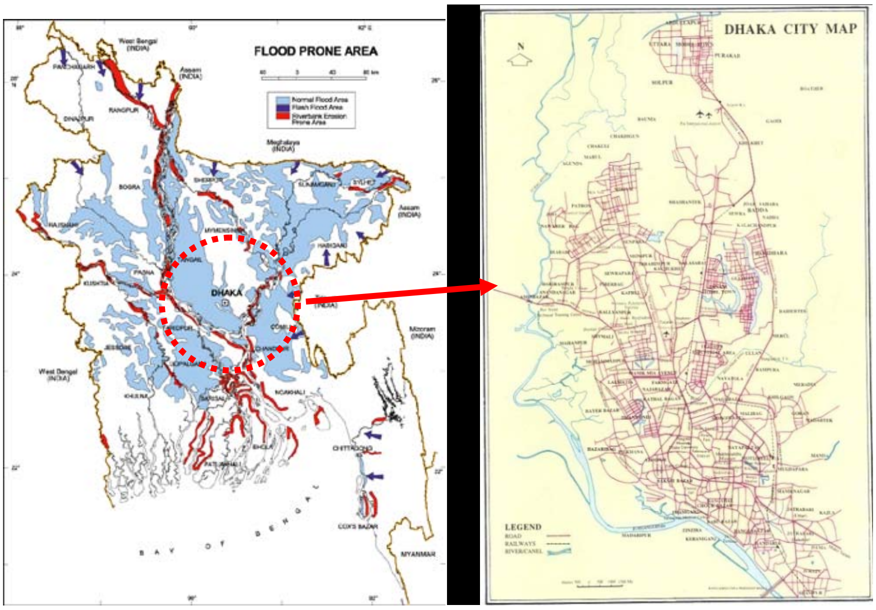


Figure 1: L-R: Flood prone areas of Bangladesh, Dhaka city (Blow up)

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

The low lying area of Dhaka city, which is mainly the Eastern part, is at high risk. The low lands and the water bodies act as the water retention areas which also help to sustain the natural ecosystem. Traditionally, the water retention areas of Dhaka city have been efficiently storing the excess water caused by excessive rainfall and the khals (canals) which are connected to the rivers gradually drain the water to the rivers, resulting in 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 lie in the Eastern part of Dhaka city. The city drainage system has not improved with the pace of rapid growth of urbanization and most of the approximately 50 canals in the city have either been filled up entirely or partially over the last two decades, consequently, these low lying areas suffer from inundation.

The Eastern area is the most vulnerable part of Dhaka city to annual flooding. The eastern part (nearly 119 square kilometres) 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.

Impacts of previous catastrophic floods

One of the most catastrophic floods in the history of Bangladesh occurred in 1998 (riverine flood). The whole Dhaka East was 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 was reported during that period. Plants and trees were directly affected due to prolonged inundation. Air quality severely deteriorated, on an average there is 50% more suspended particulate matter found in the air during the inundation period (eds. Nishat, 1999). The education system was highly disrupted due to the absence of students attending schools. This was due to multiple reasons including the inundation of roads and school buildings, health problems, diseases etc. Loss in the trade sector was also severe.

Photograph 1: Disruption of communication due to flood

Source: The Daily Star, 15 August, 2005

The latest catastrophic riverine flood occurred in 2007 and had huge impacts on Dhaka East. Many people were reported sick due to drinking contaminated water. Specifically, the health cases of diarrhoea 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 conditions of the pipelines (Islam et al. 2008). This resulted in increased water borne diseases in Dhaka East.

In 2004, even though the flooded area was much smaller than the previous floods, there was another catastrophic storm water flooding that caused huge damage to the study area. Due to a poor status of flood forecasting, substantial damage in the agriculture sector occurred, however, if the damage is monetized, the damage of infrastructure supersedes the damage to the crops. Electricity disruption also occurred due to inundation of power grids (Rahman et al. 2005).

Apart from these catastrophic floods, every year Dhaka East is flooded during the monsoon period which also causes significant damage.

Photograph 2: 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

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 that even existing adaptive measures need to be improved. The Eastern part is still unprotected[1]. This increases the urgency for the need to adapt to current climate variability and future climate change and also creating the tools for assessing different adaptation measures.

Being a developing country, there are always constraints (cost, lack of expertise and technical capacity etc) for implementing flood measures. All the measures cannot be implemented at the same time. So, there is a need to prioritize the measures and to figure out which one is needed to be implemented first to reduce the vulnerability. There is currently a lack of prioritization in the decision

[1] See Annex 1

making process in Bangladesh which could immensely help in informed decision making. Lack of proper assessment of the adaptation measures can end up with no implementation or implemented projects sometimes end up with mal adaptation. There is a gap between project proposal and project implementation. This gap is due to the lack of proper assessment of adaptation options which have never appeared in the flood management sector in Bangladesh

This research aims to provide an integrated 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 has been applied and tested at the Eastern fringe of Dhaka city. Based on the assessment and analysis, potential adaptive measures have been identified for more effective action taking into account the existing limitations. Based on the study's assessment framework and lessons from other case studies with similar context in other cities around the world conclusions have been drawn.

Literature review

Concept of vulnerability

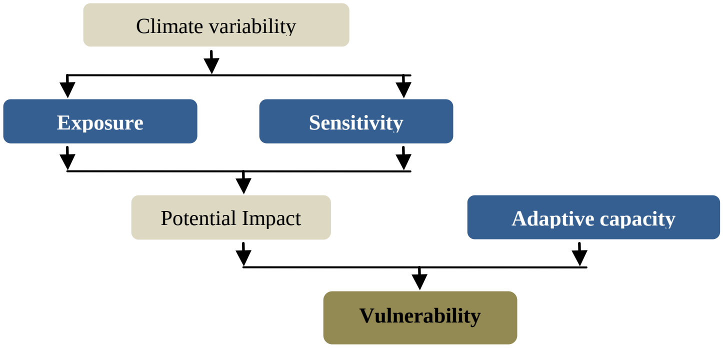
In general terms, the word 'Vulnerability' implies the degree to which a system is prone to be affected due to exposure to hazards (Turner II et al. 2003). According to United Nations (2004), hazard is defined as 'a potentially damaging physical event, phenomenon or human activity that may cause the 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 least, environmental aspect which reflects the environmental status of that region.

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 the absence of adaptation; this actually entails the external properties of the system (White, 1974). 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.

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: **Relationship between vulnerability components**



Source: This is a well know scheme for vulnerability (IPCC, 2007)

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

Vulnerability Assessment

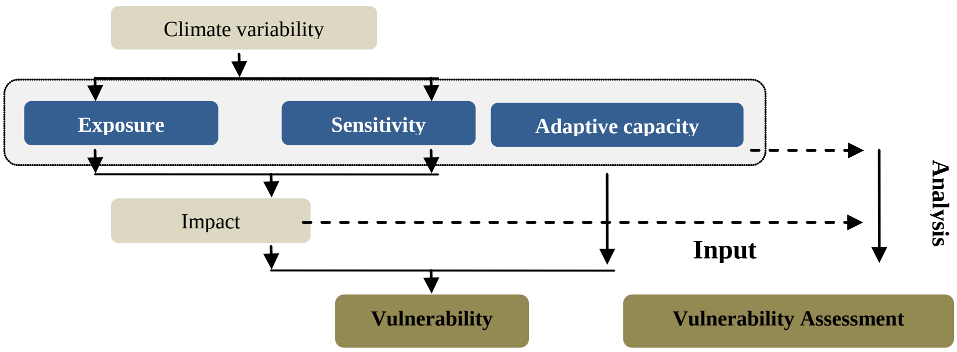
Vulnerability assessment refers to the process of identifying and quantifying the vulnerability of a system. It is a major feature for increasing climate change impacts to development planning. Over the past several decades, methods of vulnerability assessment have been developing. According to Downing 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 variability's 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, the whole process of vulnerability assessment constitutes with the sensitivity, exposure and adaptive capacity analysis. The impacts of the climate variability's are needed to be identified for the sensitivity analysis. The whole process is illustrated in figure 3.

Figure 3: Vulnerability assessment framework in relation with vulnerability components



Source: Author, 2010

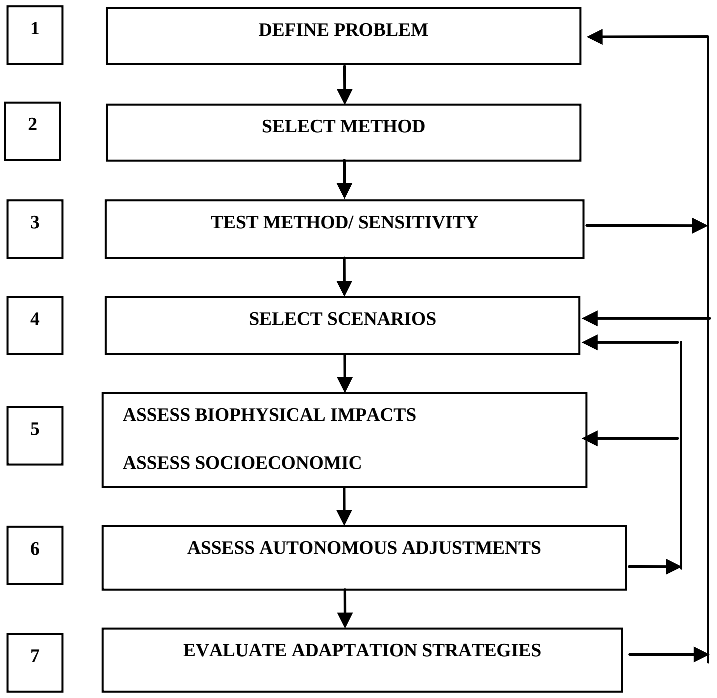
Adaptation assessment

Human beings are considered to be the most adaptable of species. Throughout history, there is evidence of human beings adapting to climate variability, sometimes by altering lifestyle or by adjusting settlements or sometimes by altering food protection systems 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 unfavourable 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 hazards and peoples' exposure to the hazards, and also reducing the impact of hazards has to also be taken into account. This is pre disaster response. While post disaster response 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.

Adaptation assessment refers to the identification of options that help to adapt to climate change, it also includes their evaluation on the basis of some criteria, for example, costs, benefits, feasibility and availability (IPCC TAR, 2001 a). Although it seems to be clear on paper it is not in practice, since there is no common set of criteria or parameters to assess adaptation options in different locations and situations. Situations vary from case to case. IPCC has developed a set of the earliest guidelines for adaptation assessment. UNDP and UNFCCC have also come up with two different types of guidelines. Methodologically these three approaches have a similar framework.

The guidelines for impacts and adaptation assessment provided by IPCC consist of seven steps (Figure 4).

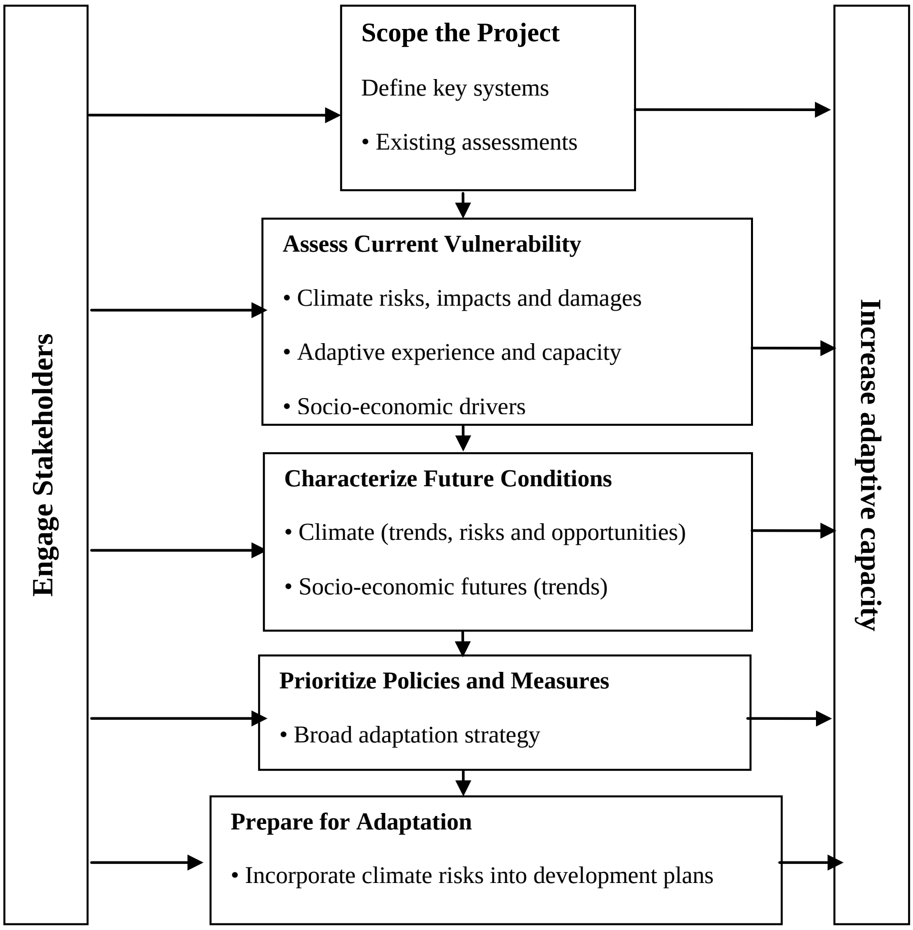
Figure 4: The seven steps of climate impact assessment



Source: Carter et al. 1994

It is clear 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 a 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 may not always be the case. Step 4 relies on climate change scenarios; this approach is directed towards the future impacts rather than present impacts and vulnerability. Another major lacking element in this procedure is the stakeholder participation. A successful adaptation needs the involvement and feedback of relevant stakeholders in every possible step. UNDP (2001) came up with an adaptation policy framework which consists of five steps (Figure 5). It takes into account both present climatic variability and future climate change. The first generation framework was more focused on climate scenarios. 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 5: 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[2]. 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 approach, since it builds upon the standard approach, it bares a resemblance to risk based approach in stage three and steps two, steps four and five corresponds to the 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 a 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 dependent on various data, whereas the task to acquire data in developing countries is not an easy job.

A major move by the UNFCCC was to facilitate the least developed countries to spot 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, 2002).

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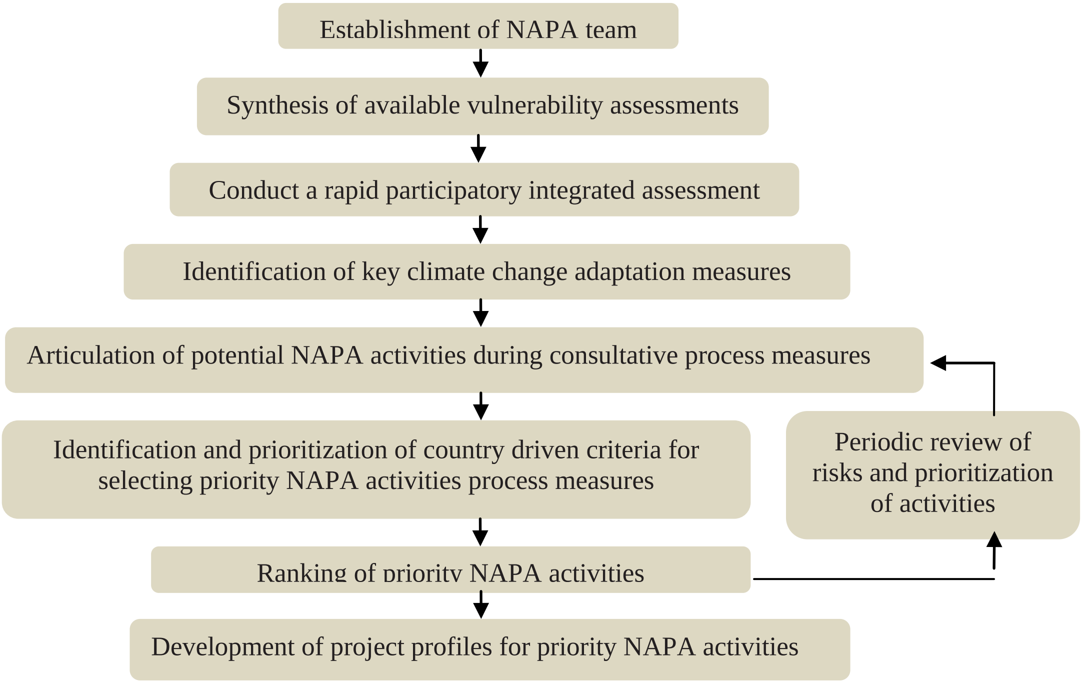
[2] See http://www.undp.org/climatechange/adapt/apf.html

“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, 2002).

Figure 6: 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 plans actions for adaptation according to that. Prioritization of adaptation activities is done according to a 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, namely, stakeholders’ involvement from all levels and the inclusion of the existing coping strategies.

Prioritization of adaptation measures

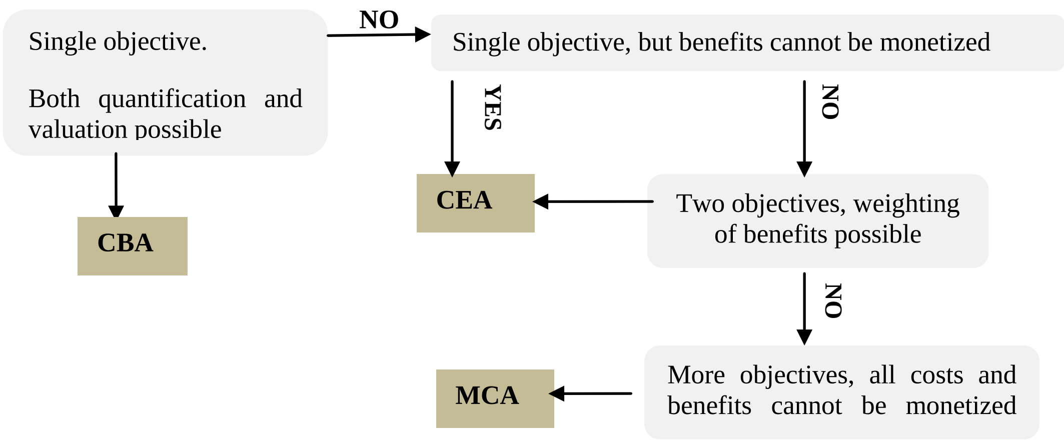
There are several techniques applied for the prioritization of adaptation options. The three most applied techniques are: Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA) and Multi-Criteria Analysis (MCA).

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 a specific measure. But it has to be expressed in monetary terms since the main purpose of it is economic efficiency[3].The

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

common factor allows 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 objectives are possible to weigh against each other.

Figure 7: What method should be used?



Source: Adjusted by Author, 2010

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. This method is appropriate for a participatory process since it employs stakeholders' participation in weighing the criteria (Brooks et al. 2009). MCA is a widely applied approach in relation to environmental issues, including climate change. In this process different 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' etc. One of the most important elements of this method is the scoring, which can incorporate monetary or non monetary data, qualitative data and diverse measurement and rating scales. In MCA the assessment criteria should be identified, the measures are assessed on the basis of their performance towards the selected criteria (scoring) and criteria should be weighted according to stakeholders' preferences. There are various techniques for weighting the criteria (Grafakos et al, 2010a). Uncertainties of certain input variables should be explored with regard to the impact to the final results by performing a sensitivity analysis.

There are examples of successful applications of the MCA method for the assessment of adaptation measures and options in various country contexts; urban flood risk assessment in Germany (Kubal et al.2009), ranking of adaptation options for climate change in the Netherlands (Bruin et al. 2009), decision making process for policy planning in Canada (Qin et al. 2008). It has also been used to locate flood vulnerable areas by incorporating GIS into the MCA aiming to assess flood risk (Yahaya, et al., 2007). This method has been applied in other sectors as well for adaptation measures assessment. For example, it has been applied in the agricultural sector for the identification of vulnerability and the assessment of alternative crop options (Julius, et al., 2009). To the best of our knowledge the MCA method has not been applied at a city level of a low income country for the assessment of different adaptation options.

Box 1: 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 suggests 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. It is also used when 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. This locally driven group of 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 for assessing the adaptation options

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

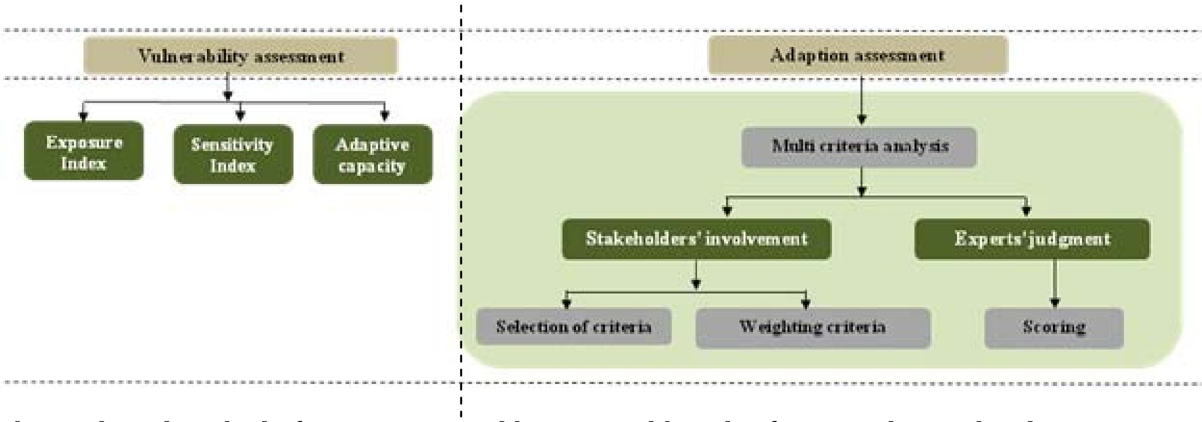
Based on the review UNFCCC's NAPA framework can be adjusted and applied in the current research context. Multi criteria analysis which is also suggested by the UNFCCC's adaptation framework for least developed countries is a prioritization method that takes into account different criteria at the same time. This is critical for those countries where climate change has multifaceted impacts, data is not always available and converting climate change impacts in monetary terms is difficult. Therefore conducting a CEA or CBA is a very difficult exercise. Moreover, involvement of multiple stakeholders reduces the possibility of biasness as well since a wide range of perceptions is taken into account. In the research work, the major emphasis is in assessing the adaptation measures and prioritizing those with a view from the stakeholders and experts' judgment.

The aim of this research is to explore and assess adaptation measures to reduce the vulnerability of the Eastern fringe of Dhaka city. The research aims to investigate and assess the adaptation options to deal with flooding and prioritize the most effective adaptation options. This entails a detailed analysis of the impacts of flooding as well as the assessment framework for the adaptation options within the specific context of flooding.

Methodology

The assessment framework is based on vulnerability and adaptation assessment. Vulnerability assessment is performed based on exposure, sensitivity and adaptive capacity analysis. Adaptation assessment is conducted based on a specific methodology of 'Multi Criteria Analysis' (MCA) which allows both normative judgment and technical expertise in the assessment process. The framework is inspired by the NAPA guidelines for least developed countries. The NAPA process uses the 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 fulfil those needs. This has been adjusted and downscaled at the local urban level which can be termed as 'Local Adaptation Programs of Action' (LAPA). Figure 8 shows the overall integrated assessment framework where vulnerability assessment and adaptation assessment are the main parts.

Figure 8: Assessment framework



This analytical method of MCA is assisted by an Excel based software tool, namely Climate Actions Prioritization (CLIMACT Prio)Decision Support Tool which has been developed by the Institute for Housing and urban development Studies (IHS). Climate Actions Prioritization tool is a climate awareness, decision support and capacity building tool for the assessment, prioritization and quick screening of climate change mitigation and adaptation measures at a local level.

CLIMACT Prio applies a multi-criteria approach to assist decision makers and urban planners to identify a wide range of decision criteria and set priorities among objectives. This method does not necessarily identify an "optimal" adaptation option, but rather requires the user to draw conclusions by looking at different components of the whole picture of the assessment problem. CLIMACT Prio provides an interactive format to help users to structure and define the decisions under consideration. The software asks the user to enter information through a guided menu of instructions and uses a menu-driven graphic representation of results for the evaluation of adaptation options. The user selects specific "actions" or adaptation options and criteria and then assigns scores (qualitative and quantitative) for how each option meets each criterion. To run CLIMACT Prio, the user needs Microsoft Windows Office (2003 or higher) and Microsoft Excel (2003 or higher).

Research is based on both primary and secondary data. Primary data was collected by *In-depth interviews (Expert judgment)*, *Focus group discussions*, *Questionnaire survey* and *Direct observation*.

The following methodological steps were followed in order to perform the assessment of different adaptation measures:

Step 1- Vulnerability assessment: Framing the decision making context

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 determine exposure: frequency, spatial extent, and duration of different types of current flooding hazards. To perform this task, secondary data was collected by desk research.

Each hazard was given a score on a scale ranging from 1(min) to 3(max). 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). The formula for calculating exposure index is:

$$E.I.i = Sum(Hij) / n * (maxHij)$$

Where E.I.i is the exposure index of Hazard i, Hij is the value of exposure attribute j of hazard i, n is the number of exposure attributes (in this case 3) and max Hij is the maximum value that an exposure attribute j can score (in this case 3).

The next step under this decision making context is to create a Sensitivity matrix to identify the *Sensitivity index*. The impacts of specific flooding hazards 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 over last three decades.

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. The formula for calculating sensitivity index is:

$$S.I.i = sum (Aij) / n * (maxAij)$$

Where S.I.i is the sensitivity index of capital asset i, Aij is the value of asset sensitivity i to hazard j, n is the number of hazards (in this case 3) and max Aij is the maximum sensitivity value that capital asset i can score with regard to hazard j (in this case 5).

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 the scope of this paper. Therefore the adaptive capacity of the whole area has been assumed as the same based on common characteristics of the population and their access to infrastructure services.

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

Vulnerability Index is the indication of the level of vulnerability of the area to the climatic hazards. Therefore, to calculate vulnerability index, all these three components should be considered.

The common formula for estimating the vulnerability index is:

$$V.I. = S.I. * E.O. / A.C.$$

Where V.I. indicates the average vulnerability index of the area, S.I. indicates the sensitivity index of the area, E.I. indicates the exposure index of the area to hazards and A.C. indicates the adaptive capacity of the area. The value of adaptive capacity is assumed as 1 which consequently leaves sensitivity and exposure indices as the main determinants of the vulnerability index.

Vulnerability for each type of capital asset i is calculated for each category of flooding (climatic hazard) by multiplying Sensitivity Index (S.I) and Exposure Index (E.I). The formula for calculating Vulnerability Index of a capital asset to a hazard is:

$$V.I.ij = S.I.ij * E.I.j$$

Where V.I.ij indicates the vulnerability index of capital asset I to hazard j, S.I.ij indicates the sensitivity index of capital asset i to hazard j, E.I.j indicates the exposure index of the area to hazard j.

Vulnerability index per type of capital asset for flood in general for the study area, is calculated by estimating the average vulnerability index of each type of capital asset per type of hazard.

Step 2: Selection of potential adaptation options

According to the vulnerability index, adaptation options are selected for assessment to reduce the vulnerability based on case studies bearing similar context. And also all the proposed adaptation options by the government for the study area have been undertaken for assessment.

Step 3: Stakeholders' criteria selection

In order to perform an adaptation (measures) assessment, criteria should be identified. Criteria are selected in a participatory manner keeping in mind the most significant considerations for the adaptation options. These criteria have been finalized by stakeholders through a focus group discussion. This participatory approach of selection of criteria ensured the inclusion of stakeholders' preferences in the decision making process at an early stage. Criteria must fulfil some qualitative attributes as described by Hajkowicz et al. (2000), Belton and Stewart (2002) and Grafakos et al. (2010b):

- *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.

Taking into account the above mentioned attributes, the criteria were selected.

In addition to the above conditions a few more conditions that are relevant to our context were identified namely:

- *Relevancy to a developing country context*: Criteria should be applicable to a developing country context
- *Local representation:* Criteria should reflect local conditions

Step 4: Experts' impact judgments: Scoring of adaptation options

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. This step ensures the inclusion of technical expertise in the assessment process.

Step 5: Standardization of scores

After the scoring of adaptation options, the scores are then standardized. Different units used to score the criteria, were standardized to a common scale with the aid of the CLIMACT Prio software.

Step 6: Stakeholders' focus group discussion on 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 a result of the discussion as consensus. The formula for estimating the criteria weights is:

$$Wi = Vi / \sum_{n} V,$$

where W_i stands for weight of criterion i, V_i stands for importance value assigned by stakeholders to criterion i, indicates the summation of importance values assigned by stakeholders to criteria and n indicates the number of criteria.

Step 7: Prioritization of options

Adaptation options are prioritized based on the final weighted scores per option.

The formula for weighted scores is:

$$WS_j = W_i * S_{ji},$$

where WS_j indicates the weighted score of option j, W_i stands for the weight of criterion i, S_{ji} stands for score of option j to criterion i.

This is the last step of the analysis and process. It is resulted with the final outcome of the prioritization of the most efficient adaptation measures for the study area based on the simple weighted summation formula and final ranking of different options . The formula of the weighted summation is:

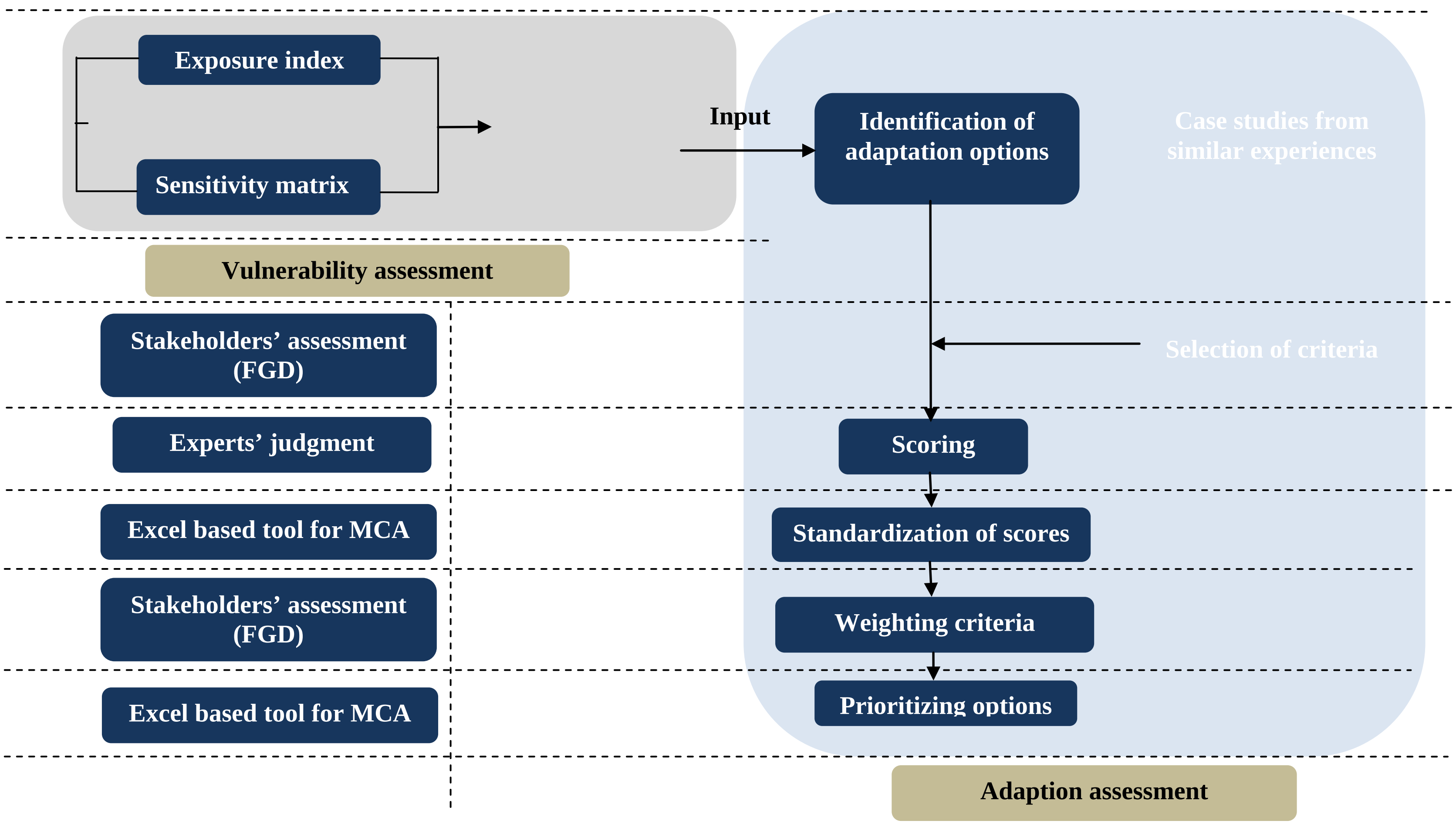
$$FSj=\sum WSij$$

Where FSj indicates final score of option j and indicates the summation of weighted score of option j.

Step 8: Sensitivity Analysis

Sensitivity analysis is conducted to investigate how sensitive the result is to the variables (criteria weights). It is a way to incorporate the uncertainty and range of stakeholders' preferences. Different scenarios have been considered by changing the variables (criteria weights). For each scenario, one variable has been changed at a time keeping the rest constant.

Figure 9: Data analysis scheme



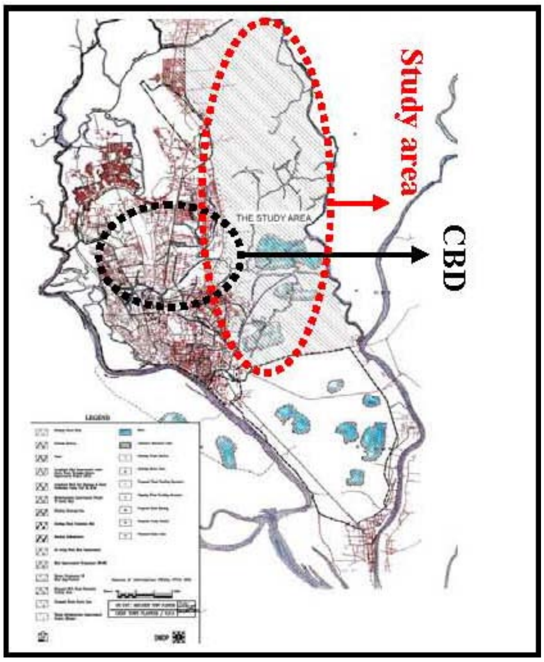
1. Case study: Dhaka, Bangladesh

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[4]. 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[5]. The planning of a bypass road for Dhaka city is encouraging the expansion more eastward due to locational advantage and close proximity to the Central Business District (Figure 10).

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 kilometres 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 10: Location of study area in the Dhaka city map



Source: BCAS, 2009

The Eastern fringe is defined as a 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 the 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). These water bodies are rapidly decreasing because of land filling by private developers, even after the ratification of Water Body Conservation Act, 2000 according to which any kind of development is prohibited in the wetlands.

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[4] See http://www.dhakacity.org/Page/About_us/About/Category/2/About_us_info

[5] See http://www.bdix.net/sdnbd_org/world_env_day/2005/bangladesh/index.htm

Land use typology

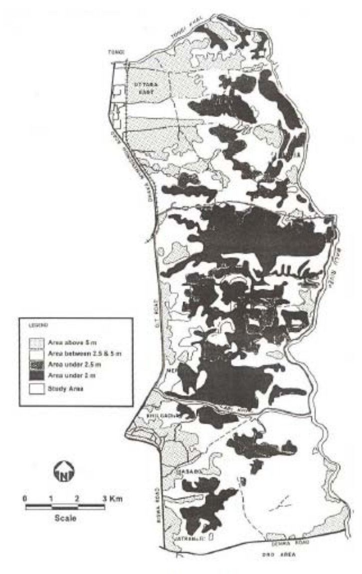
DMDP (Dhaka Metropolitan Development Planning) areas have been divided into 26 spatial planning zones and subzones (SPZs). The area in between Pragati Sarani and River Balu (SPZ-12) is defined as the Eastern fringe which is characterized as a *low lying* area with predominant *existing mixed use spontaneous zone* and *planned residential area* developed by private companies. Dynamics of the growth is identified as '*Densifying*' indicating *more people are coming in*. The eastern fringe outskirt area which is bounded by Balu and Lakhya River is documented as Razuk East (SPZ-19). This area is mainly sub urban in character with industrial development. The land use map of Dhaka 1976 shows that the land use characteristics of this area are rural. Later, private owners converted this land predominantly for residential use. The fast pace of development in the area is evident from figures 10 & 11.

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 the 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. The majority of the land in the middle part has an elevation of less than 2.5 meters.

A 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.

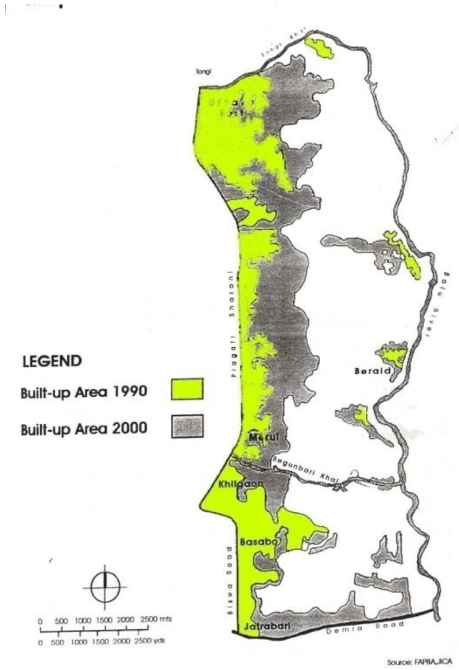
Figure 11: Land height of the study area



Map-EXISTING TOPOGRAPHY

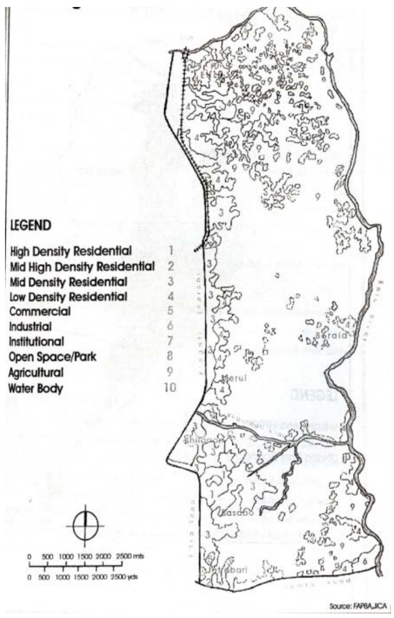
Source: FAP 8A, JICA, 1992

Figure 12: **Increase of built up area**



Source: FAP 8A, JICA, 1992

Figure 13: **Existing land use**



Source: FAP 8A, JICA, 1992

Proposed adaptation measures

After the catastrophic floods of 1987 and 1988, the Government of Bangladesh 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.

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

Table 1: List of suggested adaptation measures

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 declared it to be a priority project. It has been twelve years since the project was approved (1998)[6]. In August 2010, the prime minister of Bangladesh declared to revive the project in the near future which was suspended in 2003. BWDB would be the leading agency for the execution of the project.

Results

Exposure Index

The first step of vulnerability assessment is to prepare an Exposure index of current climate hazards. Table 2 shows the list of current flooding hazards in Dhaka and the exposure of the study area to those hazards. This table is filled with the secondary data gained from desk research to identify the Exposure index to specific hazard.

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

Table 2: 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:

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 (km^2): 1= 1-10; 2= 11-50; 3= over 50

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

Sensitivity matrix

The next step in order to frame the decision making context is to create a Sensitivity matrix to identify the sensitivity index. The following table 3 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.

The sensitivity index illustrates the degree or level of sensitivity of each type of capital asset to climatic hazards.

The sensitivity index shows that *water quality* (natural asset) is the most sensitive sector due to flooding bearing a very high (93.3) index. Then the next most sensitive sector is the *infrastructure* (physical asset) having an index of 86.7. *Trade* (economical asset) is also very sensitive to flooding bearing an index of 80.

Analysis of adaptive capacity

The adaptive capacity is mostly observed as the household's or community's vulnerability (Few, 2003). 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. The survey conducted on the study area shows that there is a dominant group bearing the same status in each considered category for adaptive capacity (i.e. age, occupation, income level, education, existing infrastructure services). Therefore, taking into account that the dominant group in each considered factor for adaptive capacity and equal access of all the inhabitants to the existing infrastructure services, it can be assumed that the whole study population bears the same adaptive capacity.

Vulnerability Index

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 4 shows the vulnerability index for each considered sector based on calculations according to formula (3).

Table 3: 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*** [7]				
	Flora and fauna	4	3	2	**60**
	Water quality	5	5	4	**93.3**
	Air quality	4	3	1	**53.3**
	Soil contamination	4	2	1	**46.7**
Physical	***Property , goods and services*** [8]				
	Shelter/ housing and other assets	4	3	2	**60**
	Infrastructure	5	4	4	**86.7**
Economical	***Productive sectors***				
	Agriculture	3	3	4	**66.7**
	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	**66.7**

[7] See Annex 3

[8] See Annex 4

Table 4: 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***	**42.2**
	Water quality	93.3		***83***	93.3		***72.8***	93.3		***41.2***	**65.6**
	Air quality	53.3		***47.5***	53.3		***41.6***	53.3		***23.6***	**37.5**
	Soil contamination	46.7		***41.5***	46.7		***36.4***	46.7		***20.5***	**32.8**
Property, goods and services	Shelter/ Housing and other assets	60		***53.4***	60		***46.8***	60		***26.4***	**42.2**
	Infrastructure	86.7		***77.1***	86.7		***67.6***	86.7		***38.1***	**60.9**
Productive sectors/ livelihoods	Agriculture	66.7		***59.3***	66.7		***52***	66.7		***29.3***	**46.9**
	Trade	80		***71.2***	80		***62.4***	80		***35.2***	**56.2**
	Fisheries	40		***35.6***	40		***31.2***	40		***17.6***	**28.1**
Stakeholders/ livelihoods	Squatter and slum dwellers	80		***71.2***	80		***62.4***	80		***35.2***	**56.2**
	Land owners	40		***35.6***	40		***31.2***	40		***17.6***	**28.1**
	Tenants	26		***23.1***	26		***20.3***	26		***11.4***	**18.5**
	Agricultural workers	60		***53.4***	60		***46.8***	60		***26.4***	**42.2**
	Traders and businessmen	66.7		***59.3***	66.7		***52***	66.7		***29.3***	**46.9**

The most vulnerable types of capital assets are depicted in table 5 where they have being ranked according to the vulnerability index.

Table 5: **Ranking of vulnerable sectors**

Rank	Types of capital assets	Category	Vulnerability Index (Scale 1 -100)
1	Water quality	***Natural***	**65.6**
2	Infrastructure	***Physical***	**60.9**
3	Trade	***Economical***	**56.3**
	Squatter and slum dwellers	***Social***	
4	Agriculture	***Economical***	**46.9**
	Traders and businessmen	***Social***	
5	Flora and fauna	***Natural***	**42.2**
	Shelter/ housing and other assets	***Physical***	
	Agricultural workers	***Social***	
6	Air quality	***Natural***	**37.5**
7	Soil contamination	***Natural***	**32.8**
8	Land owners	***Social***	**28.1**
	Fisheries	***Economical/ Natural***	
9	Tenants	***Social***	**18.3**

Water quality is the most vulnerable sector in the study area based on table 5. Vulnerability of infrastructure and trade sector is also dominating the chart. For example, the 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.

Selection of potential adaptation options based on Vulnerability index

All the existing proposed adaptation options have been selected for assessment. Two other options have been proposed from the case study bearing similar context, based on Vulnerability Index. Enhancing the emergency response mechanism is considered as one of the proposed options based on the 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 an early warning system has also been proposed as additional measure. Agriculture is a sector identified to be highly vulnerable to flooding; therefore enhancing an 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 the early warning system in Dhaka is found to be significantly poor. The principal institution responsible for this is the ‘Flood Forecasting and Warning Center’ (FFWC). FFWC does not have enough stations to measure the river water level and is highly dependent on the 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 was 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 the ‘Disaster Management Bureau’. It was 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 into 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 a community based management program where the initial cost is much lower.

Table 6: List of adaptation options

Existing proposed measures	Construction and up gradation of storm sewer/ drainage system
	Raised road
	Embankment
	Flood wall
	Canal Improvement
	Protection of water retention areas
Proposed measures from relevant cases based on vulnerability index	Enhancing emergency response mechanism
	Enhancing early warning system

Stakeholders' criteria selection

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 (FGD) was 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 categories. Prior to the FGD, each representative was asked to prepare a set of criteria according to their own perspectives. This was done to avoid potential bias during the discussion. The criteria (Table 7) were finalized as a consensus from the FGD. The objectives of the finalized criteria were also decided from the FGD, for example, the criterion 'Cost' has to be minimized while the criterion 'Vulnerability reduction' has to be maximized.

Table 7: **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 8: 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

Experts' scoring of criteria

Scoring of each adaptation option based on the criteria is performed by selected experts. Secondary data has been used for the criterion 'cost'. 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 judgements for scoring covered the major concerns which should be considered during assessing adaptation options in the studied context. Table 9 has been formulated by making average of scores given by the experts for each option against specific criterion.

Table 9: Scoring of adaptation options

Adaptation Options			Criteria						
			Vulnerability reduction (in percentage)	Minimization of Costs (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 required (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

Legends:
Green color Indicates best performance
Red color Indicates worst performance

Figure 14: Radar graphs for scores for each adaptation option against selected multiple criteria

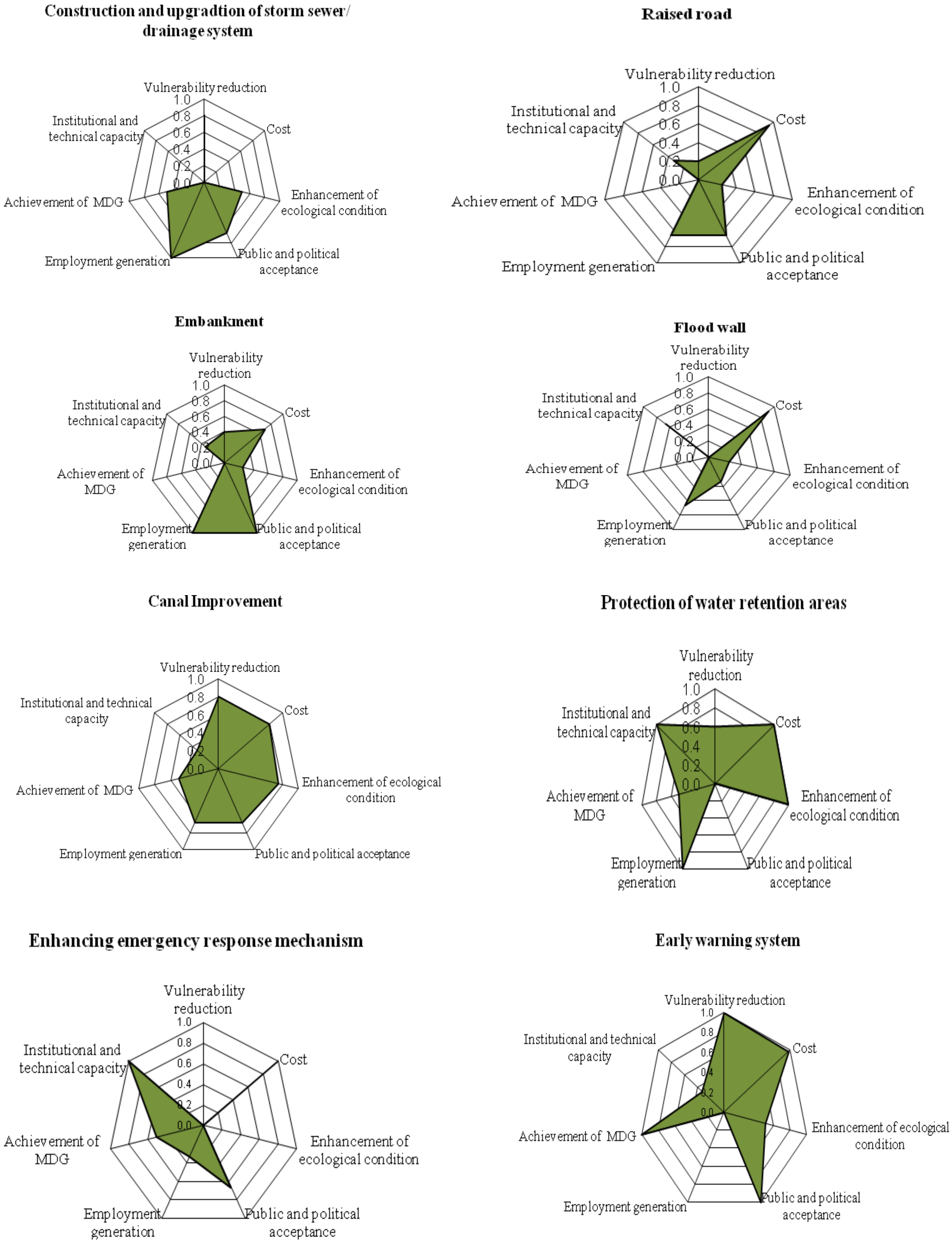


Figure 14 illustrates a visual way of how each adaptation option performs on specific criterion according to experts' judgements. These have been prepared based on the standardized scores of the experts.

Weighting of criteria

Weighting of each selected criterion is done based on a second round of a focus group discussion (FGD) with the stakeholder group. It ensures the inclusion of stakeholders' preferences in the adaptation assessment process. The idea behind the second FGD was to determine the degree of relative importance of each criterion on the basis of the scored table by experts (Table 10). The stakeholders are requested first to express verbally the relative importance of criteria based on a scale from very low to very high and then to determine which arithmetic value associated with the different level of importance, better reflects their preferences. The weighting scales are shown in table 11. The stakeholders had to choose a specific importance level and one of the values assigned for that importance level.

Within the same importance level, there were two different degrees (values), from which one had to be selected (see table 11). For example, for high degree of importance, there were two corresponding values, 80 and 70. One of those two had to be chosen. This was 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.

Table 10: Weighting scale

Importance level	Values	
Very High	90	100
High	70	80
Moderate	50	60
Low	30	40
Very Low	10	20

They have been asked to weight the criteria before the FGD according to individual perspective. This was done to avoid bias during the FGD. Table 12 shows the outcome (consensus) of the second FGD. An interesting outcome of the second FGD 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. The weights have been determined based on the normalization on the values given by the stakeholders derived from formula (4) mentioned in the methodology section.

Table 11: 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 15: Criteria weights

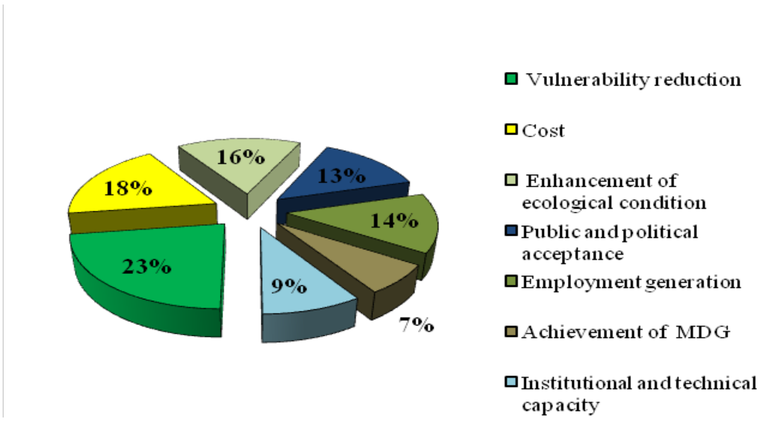


Table 12 also shows the impact range of each criterion based on the range between highest and lowest score for each criterion. For example, the criterion 'vulnerability reduction' has '85' as highest score and '60' as lowest score. So, the impact range for 'vulnerability reduction' is (85 - 60), that is, 25.

Weighted scores

The scores given by the experts are combined with the weights decided by the stakeholders in order to get the weighted scores.

Table 12: Weighted score

Final Score	Adaptation Options	Vulnerability Reduction	Cost	Enhancment of ecological condition	Public & political acceptance	Employment Generation	Achievement of MDGs	Institutional and technicalcapacity
	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	0.08	0.09	0.14	0.03	0
0.47	Raised road	0.05	0.17	0.04	0.09	0.09	0	0.03
0.56	Embankment	0.09	0.13	0.04	0.14	0.14	0	0.03
0.4	Flood wall	0	0.17	0.04	0.05	0.09	0	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	0.14	0.03	0.09
0.44	Enhancing emergency response mechanism	0	0.18	0	0.09	0.05	0.03	0.09
0.72	Enhancing early warning system	0.23	0.18	0.08	0.14	0	0.07	0.03

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

Prioritization of adaptation options

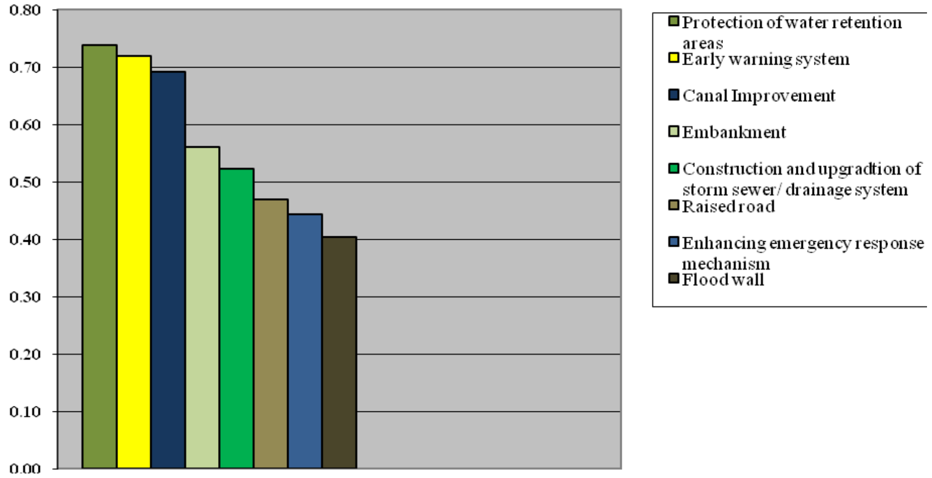
Prioritization of adaptation options is done based on the final weighted scores per option.

Table 13: 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 13, it is vivid that the top three priorities 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 16: Ranking of adaptation options

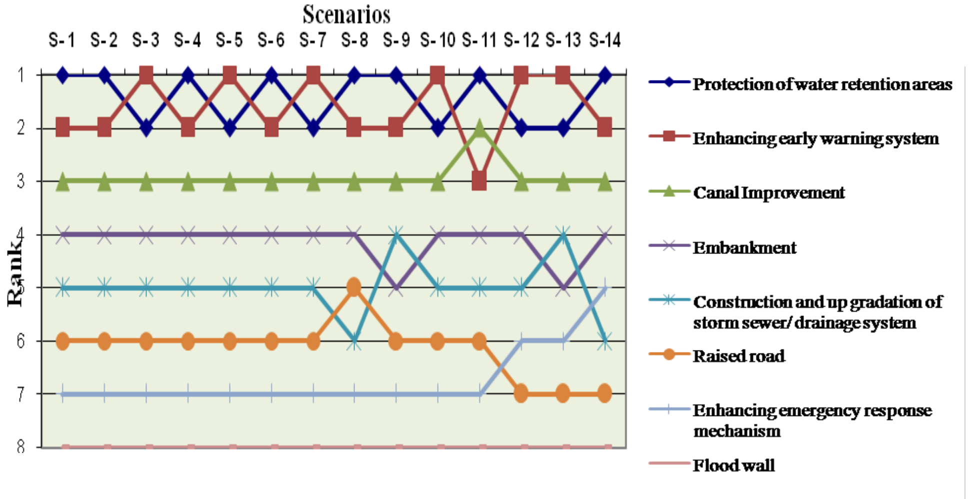


Sensitivity Analysis

Fourteen scenarios have been considered to perform the sensitivity analysis. Scenario 1 to 7 shows change in variable weight by 20 units and scenario 8 to 14 shows change in variable by 40 units. It is found that by changing one criterion weight by 20 units and keeping the rest constant, there is no significant change in the ranking.

There are small changes if one criterion weight is changed significantly (40 units) keeping the others constant. But again, if the options are categorized in three broad 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.

Figure 17: Sensitivity Analysis



Therefore, based on the sensitivity analysis, it can be concluded that the results are quite robust with regard to the variable of criteria weights.

Discussion

Based on the outcome of the vulnerability assessment, the most vulnerable types of capital assets to flooding have been identified. This is the primary activity to perform in order to select adaptation options. In order to reduce the vulnerability of the identified sectors, appropriate measures are selected. Water quality is identified to be the most vulnerable sector, followed by infrastructure and trade sectors. Livelihood of squatters and slum dwellers are under high risk to flooding which determines their low adaptive capacity and high exposure and sensitivity to flooding. An indepth impact assessment was conducted a decade before, after the catastrophic 1998 flood and the outcome resulted with similar results (Nishat, 1999). Therefore, the first measures that should be taken should be to protect these sectors.

The main aspects and list of criteria to be considered during the adaptation assessment process have been significant findings of the research which was due to the stakeholders' direct involvement. These have resulted from discussions which limits the risk of institutional or personal bias. Seven main aspects have been distinguished as criteria categories including: vulnerability, financial, environmental, socio political, macroeconomic, socio-economic, institutional and technological. The direction of preference of the criteria were also identified by the stakeholders like, which criteria are needed to be maximized or minimized, for example the cost and required institutional and technical capacity should be minimized. Since the stakeholder group includes representatives from various groups including; community, governmental and nongovernmental organizations, the identified criteria encompass a range of perceptions from different categories of people. Based on stakeholders' preferences, vulnerability reduction, cost, enhancement of ecological condition, public and political acceptance, employment generation have been identified as the most significant criteria, while achievements of MDG, institutional and technical capacities, have been judged as less significant. This was also an interesting outcome, since there is 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 due to the fact that flood hazard poses serious risk to the livelihood itself of the people of the study area. Therefore, the stakeholders are more concerned about saving that rather than being concerned about national and global issues. The community representatives were not very aware of the MDG, this actually contradicts the general status of MDG achievement for Bangladesh on the national scale, since Bangladesh won the UN award for its MDG achievements in 2010[9].

The final outcome of the research is the ranking of the adaptation options. The ranking shows protection of the water retention area, enhancing early warning systems and canal improvements 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 has been proved to be a far less prioritized measure. Apparently if the drainage system is improved, it is expected to reduce flooding, but for a under developed country there are other factors that should also be considered. Construction and up gradation of the drainage system requires quite a high budget and also high technical capacity which is less available in the context. So, protection of the water retention area has proved to be relatively the most effective option for the study area for reducing vulnerability to flooding considering the relative importance of criteria along with the existing budget and capacity constraints.

Uncertainty of stakeholders' preferences has also been incorporated by performing a sensitivity analysis. Sensitivity analysis of the results to the criteria weights (input variables) shows that the results are quite robust with regard to changes of the criteria weights**.**

Implications of the study

The current study has certain policy oriented and decision making related implications:

- Firstly, the most vulnerable types of capital assets of the study area to flooding are identified by the research (vulnerability assessment). It can assist policymakers in formulating sectoral

[9] See http://www.theindependentbd.com/natioanal/10195-hasina-receives-un-award-for-bangladeshs-mdg-achievements.html

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.

- Secondly, the adaptation assessment procedure for flooding of the study area would be benefitted if the most important criteria are considered during the assessment (see table 7 & 10) Their importance level have been identified by the research. This is based on the incorporation of stakeholders' preferences. Thus stakeholders' preferences will be brought to light before those of the decision makers. The stakeholder group also includes the root level representatives (i.e. farmer, business group) of the study area whose preferences are often neglected during the decision making process.

- Thirdly, 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 measures have already been proposed for the study area, but it is difficult to implement all of the measures at the same time. The prioritization could help to make decisions on the implementation of the most immediate (high priority) measures to be undertaken. Moreover, the 'Enhancing early warning system', a proposed measure from the relevant case study, has shown to be one of the most effective measures to be undertaken for the study area considering the limitation of cost, institutional and technical capacity.

- Fourthly, the problem of vulnerability of Dhaka East to flooding, that has been addressed by this study is a crucial concern today in Bangladesh. There are proposed adaptation measures to reduce the vulnerability of the area but they have not yet been 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 been able to indicate which measures could be implemented first for reducing the vulnerability of the EFA.

Furthermore the current application has methodological implications which can be summarised:

- The methodology adapted for the research can be useful for the researchers to use it as an example of how MCA can be applied for flood management incorporating vulnerability and adaptation assessment in a structured way within a developing countries' context on an urban scale. This methodology ensures transparency and multidimensionality by considering multiple criteria and multiple stakeholders' preferences while including both relevant stakeholders and experts. The experience of MCA application all over the world[10] shows similar outcomes in line with the research itself.

Conclusions

The magnitude of flood risk and climate variability is expected to increase in the future as a result of climate change. Therefore, the vulnerability of developing countries will also increase. For a sustainable future and for the survival of millions of people in developing countries, there is urgent need to adapt to this variability. The adaptation assessment undertaken by this research provides significant support to policy design and decision making for a least developed country like Bangladesh, where resources are limited and the vulnerability to climate change very high.

The main objective of the study was to prioritize adaptation measures for flooding. The provision of effective prioritization is a challenging goal. In this research, this prioritization has been done

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[10] See Literature Review

considering the constraints of budget, institutional and technical capacity. Vulnerability assessment identified the sectors most at risk which lead to select the adaptation options to be assessed within the boundaries of the study area. The assessment of adaptation options is based on both subjective (experts' scoring) and objective (actual cost) information. Moreover, stakeholders' inclusion in the decision making process for eliciting their preferences has also been ensured by the focus group discussions. Therefore, the prioritization of adaptation options is determined by stakeholders' consultations to a certain extent. The exchange of information from a multitude of perspectives of the stakeholders made the outcome of the decision making more legitimate and defensible. It is worth to mention that the whole process of including these two groups (experts and stakeholders) builds a platform for knowledge generation.

The integrated adaptation assessment method applied for this study includes experts' judgment and stakeholders' preferences and incorporates vulnerability assessment and adaptation assessment. The whole process of prioritization allows a gradual approach to the decision problem providing a structured utilization of stakeholders' preferences. This participatory assessment framework 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 provided a communication and knowledge generation platform and made the outcome of the decision making more legitimate and defensible.

Limitations and scope for further research

The current application demonstrated the use of a prioritization assessment method for the quick screening of adaptation measures in a developing country context as well as taking development aspects into account. For a more thorough and in depth assessment, the frameworks for both vulnerability and adaptation impact assessment stated in the study require considerable research. For example, the likely impacts for each adaptation option can be generated by a detailed impact assessment consisting of different projects in order to get more specific data which can be based on different parameters, i.e. diverse aspects of flooding, adaptation details, and neighbourhood context. That would require an in depth ex ante impact assessment along with institutional, technical and financial enhanced capacity.

And again different judgment could be gained on the basis of different perspectives, i.e. experts, different groups of people from the considered area (business, agriculture, squatters etc), government. A larger sample of stakeholders could be taken to map their preferences.

The assessment could also take into account different temporal scales, i.e. short term, medium term, long term. Moreover, it could be tested further on criteria weighting, such as using different techniques of assigning weights or investigating different methods for the aggregation of criteria (Grafakos et al, 2010).

An adaptation option to be applied is not a discrete decision, nor based on reducing vulnerability to certain climatic hazard alone. There are other considered factors within the studied context like limited budget, limited institutional and technical capacity, land reclamation that might constrain the implementation of the option and so on. The outcome of the evaluation can be complemented (or validated) by methods like cost benefit and cost effectiveness analysis.

Climate change poses multifaceted risks of flooding which is not always possible to take into account within the application of the MCA method. Multifaceted risks are likely to be undertaken by a broader decision making process like risk management. MCA can provide information giving 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. Flooding is a sensitive sector exacerbated by climate change and entails a wide range of risks. Therefore, the integration of risk management in a broad MCA assessment process can be a direction for further research.

References

Alam, M. & Rabbani, M. G., 2007, Vulnerabilities and Responses to Climate Change for Dhaka. *Environment and Urbanization*, vol. 19**,** pp. 81-97.

Annotated guidelines for the preparation of National Adaptation Programmes of Action, 2002, [Online] Available: http://unfccc.int/files/cooperation_and_support/ldc/application/pdf/annguide.pdf [2010, 5 Jan].

Bala, S.K., Islam, S., Chowdhury, J.U., Rahman, M. R., Haque, A.M., Khan, S.A., & Salehin, M., *Performance of flood control works around Dhaka city during major floods in Bangladesh*, [Online] Available: http://teacher.buet.ac.bd/akmsaifulislam/publication/ICWFM2009_Paper_39.pdf [2010, 10th January]

Belton, V. & Stewart, T., 2002, *Multiple Criteria Decision Analysis: An Integrated Approach,* Kluwer Academic Publishers, Dordrecht.

Brooks, M., Frederic, G., Harvey, H., Sauve, C., 2009, *Prioritizing Climate Change Risks and Actions on Adaptation, A Review of Selected Institutions, Tools, and Approaches,* Government of Canada, Ottawa.

Brooks, N. & W.N. Adger, 2005, *Assessing and enhancing adaptive capacity,* Adaptation Policy Frameworks for Climate Change, B. Lim, E. Spanger-Siegfried, I. Burton, E.L. Malone and S. Huq, Eds., Cambridge University Press, New York.

Bruin, K., Dellink, R. B., Ruijs, A., Bolwidt, L., Buuren, A., Graveland, J., Groot, R. S. , Kuikman, P. J., Reinhard , S.,. Roetter, R. P, Tassone, V. C., Verhagen, A. and Ierland, E. C., 2009, *Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives,* Climate change, Springer, USA.

Burton, I., Huq, S., Lim, B., Pilifosova, O., Schipper, E.L., 2002, *From impacts assessment to adaptation priorities: the shaping of adaptation policy*, Climate Policy 2, London.

Carter, T.R., Parry, M.L., Harasawa, H., Nishioka, S., 1994, IPCC Technical Guidelines for Assessing Climate Change. IPCC, Geneva, 59 pp.

Downing, T. E. & Patwardhan, A., 2002, *Vulnerability assessment for climate adaptation*, [Online] Available: www.aiaccproject.org/meetings/.../Vulnerability/TP3_Downing.doc [20th May, 2010]

Few, R., 2003, *Flooding, vulnerability and coping strategies: local responses to a global threat,* Progress in Development Studies 3, London.

Fussel, H. & Klein, J. T. R., 2006, Climate change vulnerability assessments: An evolution of conceptual thinking, [Online] Available: http://www.pik-potsdam.de/~fuessel/download/cc02_author.pdf [2010, 13th February].

Gbetibuo, G. A. and Ringler, C., 2009, Mapping South African Sector Vulnerability to Climate change and Variability, IFPRI.

Grafakos, S., Flamos, A., Oikonomou, V., and Zevgolis, D., 2010a, Multi-criteria analysis weighting methodology to incorporate stakeholders' preferences in energy and climate policy interactions, *International Journal of Energy Sector Management*, Vol. 4 No. 3, pp 434 – 461

Grafakos, S., Zevgolis, D. and Oikonomou, V., 2010b, *"Towards a process for eliciting weights and enhancing capacity of stakeholders in ex- ante evaluation of climate policies" in evaluating sustainable development,* Vol. 3, ed. By Hardi, O. & Martinuzzi, A., Edward Elgar (In press).

Hajkowicz, S., Young, M., Wheeler, S., MacDonald, D.H. & Young, D., 2000, *Supporting decisions, Understanding Natural Resource Management Assessment Techniques*, CSIRO Land and water, Canberra.

Halcrow Group, 2006, Updating/ Up grading the feasibility Study of Dhaka Integrated Flood Control Embankment cum Eastern Bypass Road Multipurpose Project, BWDB, Bangladesh.

Handbook for conducting Technology Needs Assessment (TNA) for Climate Change, 2009, UNDP, USA, [Online] Available: http://unfccc.int/ttclear/pdf/TNAHandbook_9-15-2009.pdf [2010, 13th Feb].

IPCC TAR, 2001 a., 2001, *Climate Change 2001: Impacts, Adaptation and Vulnerability. IPCC Third Assessment Report*, Cambridge University Press.

Islam, I., 2008, *Wetlands of Dhaka Metro Area: A Study from Social, Economic and Institutional Perspectives*, PhD Thesis, Japan Society of Promotion of Science (JSPS). Japan, College of Policy Science Ritsumeikan University.

Islam, S., Haque, A. and Bala, S. K., 2008, *Hydrological aspects of flood 2007,* Institute of Water and Flood Management, BUET.

JICA, 1992, *Master Plan for Greater Dhaka Protection Project, Flood Action Plan, FAP 8A,* Main Report and Supporting Reports I and II, Flood Plan Coordination Agency, Dhaka.

Julius, S. H. and Scheraga, J. D., 2009, *The team model for evaluating alternative adaptation strategies,* Global Change Research Program, USEPA

Kelly, D. L. & Adger, W. N., 2000, *Theory and practice in assessing vulnerability to climate change and facilitating adaptation*, Climate Change 47, pp. 325-352.

Khorshed, A., 2003, *Cleanup of the Buriganga River: Integrating the environment into Decision making,* PhD Thesis, Murdoch University, Perth.

Kubal, C., Haase, D., Meyer, V. and Scheuer S., 2009, *Integrated urban flood risk assessment – adapting a multicriteria approach to a city,* Natural Hazards and Earth System Sciences, Copernicus Publications, Germany.

McCarthy, J.J.,Watson, R.T. & Canziani, O.F., 2001, *Climate Change 2001: Impacts, Adaptation and Vulnerability,* (ed.) J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Mirza, M. Q.M. 2003, *Climate change and extreme weather events: can developing countries adapt?* Climate Policy 3, London.

Nishat, A., Reazuddin, M. and others, eds., 1999, *The 1998 Flood: Impact on Environment of Dhaka City,* Department of Environment in conjunction with IUCN Bangladesh.

Qin, X.S., Huang, G.H., Chakma, Nie, X. H. and Lin, Q.G., 2008, *A MCDM-based expert system for climate-change impact assessment and adaptation planning – A case study for the Georgia Basin, Canada,* Sciencedirect, USA.

Rahman, R., Haque, A. Khan, S.A., Salehin, M. and Bala, S. K., 2005, *Investigation of hydrological aspects of flood -2004 with special emphasis on Dhaka city*, Institute of Water and Flood Management, BUET.

Turner II , B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A. & Schiller, A., 2003, *A framework for vulnerability analysis in sustainability science*, Proceedings of the National Academy of Sciences of the United States of America.

United Nations Framework Convention on Climate Change (UNFCCC), 2002, *A Guide to the Climate Change Convention and its Kyoto Protocol*, UNFCCC Secretariat, Bonn.

United Nations Development Programme (UNDP), 2001, *Elaborating an adaptation policy framework with technical support papers*, UNDP, New York, USA.

United Nations, 2004, *Living with Risk: A Global Review of Disaster Reduction Initiatives*, United Nations International Strategy for Disaster Reduction, Geneva, Switzerland.

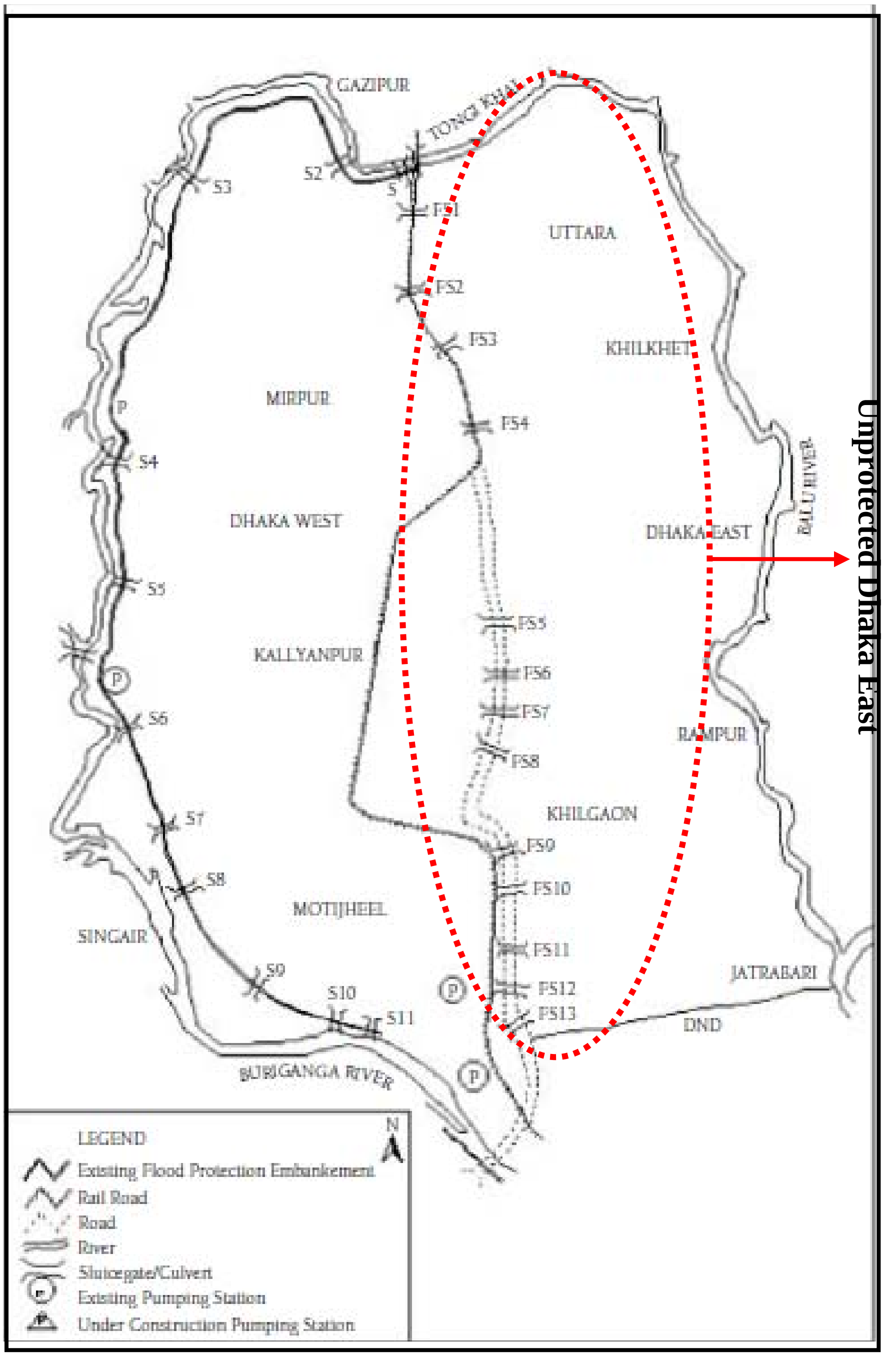
Water Body Conservation act, 2000, [Online] Available: http://www.scribd.com/doc/24865549/Water-Act-2000 [2010, 12th March].

White, G.F, 1974, *Natural Hazards: Local, National, Global*, Oxford University Press, New York.

Yahaya, S., Ahmad, N. and Abdalla, R. F., 2009, Multi criteria analysis for flood vulnerable areas inHadejia- Jama' Are river basin, Nigeria

Annex 1: Existing flood control infrastructure of Dhaka

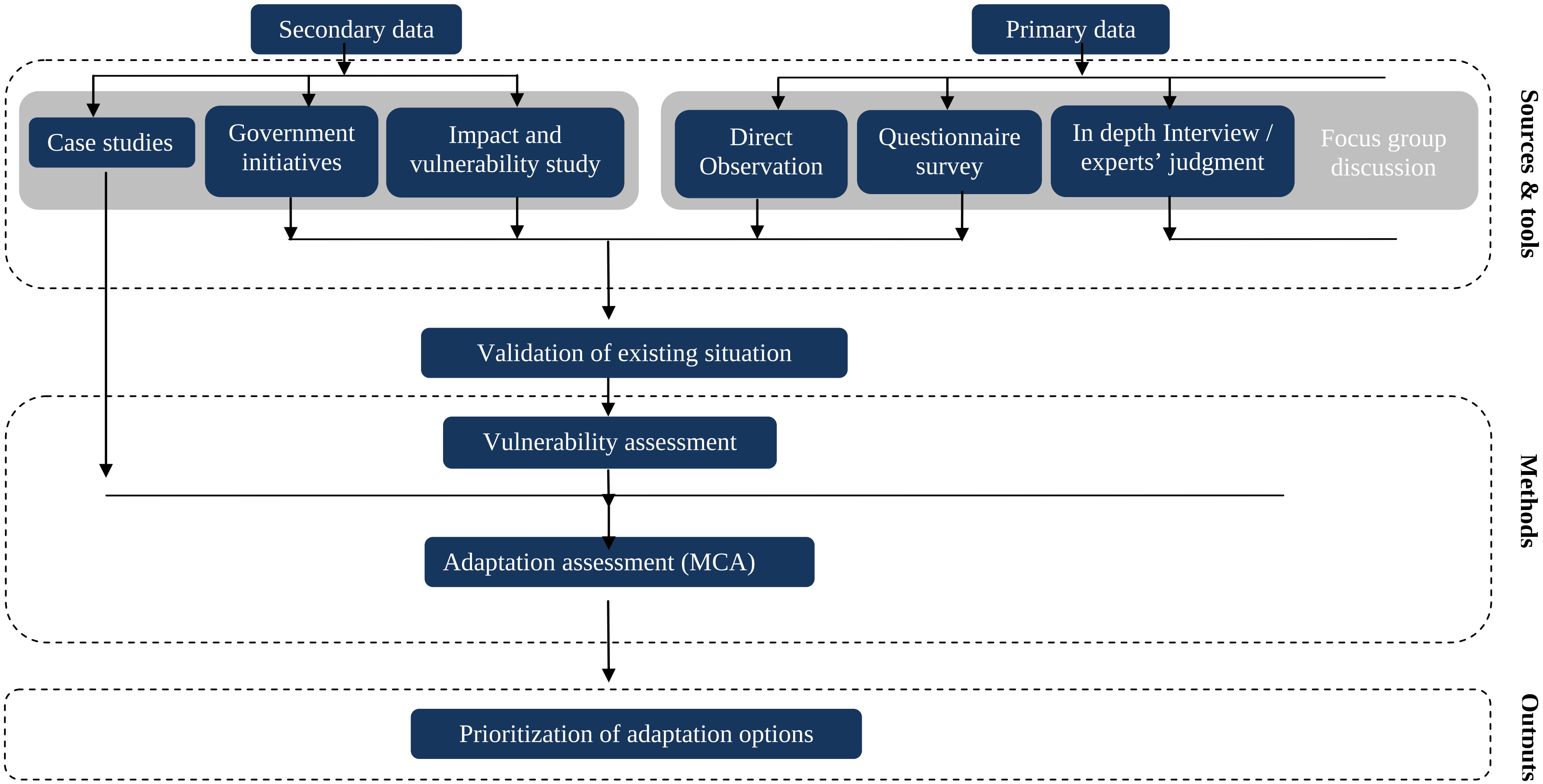
Figure 18: Existing flood control and drainage infrastructure of Dhaka, showing unprotected Dhaka East



Source: eds. Nishat, 1999

Annex 2: Analytical Framework

Figure 19: 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.



Annex 3: Considered impacts of flooding on ecosystem

Table 14: 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 4: Considered property goods and services

Table 15: 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.