JOURNAL OF MULTI-CRITERIA DECISION ANALYSIS
J. Multi-Crit. Decis. Anal. **23**, 210–224 (2016)
Published online 11 July 2016 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/mcda.1571

Application of Multi-Criteria Analysis on Climate Adaptation Assessment in the Context of Least Developed Countries

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ABSTRACT

The developing countries are suffering the most because of climatic variability and they have an enormous backlog in basic infrastructure to protect their cities. In addition, the resources and technical expertise are limited. Therefore, the adaptation measures to protect their cities are needed to be planned and prioritized carefully to reduce the vulnerability simultaneously considering the risk reduction, local constraints and development goals. A framework for prioritization of adaptation measures is lacking in the decision making in this context which could immensely assist in informed and structured decisions during the planning process of adaptation strategies in developing countries. This paper is exploring the potential of Multi-Criteria Analysis as a methodology for climate adaptation assessment in order to prioritize the adaptation measures to be undertaken. Hence in this paper Adaptation assessment is conducted within the framework of Multi-Criteria Analysis methodology which allows both normative judgement and technical expertise in the assessment process. Such a participatory integrated assessment of adaptation options is a new approach in flood management in least developed countries. The assessment framework has been applied and tested at the Eastern fringe of Dhaka city which is highly vulnerable to flooding. Based on the assessment and analysis, adaptive measures are prioritized to enable more effective action. Copyright © 2016 John Wiley & Sons, Ltd.

KEY WORDS: Climate change; Adaptation assessment; Multi-Criteria Analysis; Prioritization; developing countries; participatory

1. INTRODUCTION

Changes in the climate system are evident. Numerous changes that have been observed for last five to six decades are extraordinary warming of the atmosphere, melting of glaciers, sea level rise, extreme weather effects like droughts, floods, increasing intensity and frequency of cyclones etc. Precipitation intensity is projected to increase globally (Meehl *et al*., 2007) which has a direct influence on the risk of flooding. The changes will continue to take place over the next century (i.e. sea level rise is projected to exceed what has been observed over the last four decades) (IPCC, 2013). It will worsen the existing environmental problems of numerous countries, particularly the least developed countries (LDC) as they lack in capacity to protect their cities.

There is a pervasive disparity between the countries who are contributing to climate change and those who are facing the most risks and challenges to cope with it. The countries at high risk, in fact, are hardly contributing to the global cause of climate change, i.e. green house gas (GHG) emissions. Even so, they will likely have to undertake adaptive measures. Predominantly these are the low and middle income countries from the developing world having a massive backlog in basic infrastructure services to shield their cities.

There are multiple challenges for the LDCs to implement the planned adaptation measures, i.e. lack of technical capacity, expertise and limited resources (Mirza, 2003). On top of that, all the planned measures are difficult to implement at the same time. As a consequence nothing is happening on the ground. There is a vivid gap between project proposal and project implementation (Haque *et al*., 2012). Hence it is deemed required to assess the adaptation measures in order to identify and prioritize which are to be implemented at first hand, simultaneously considering the risk reduction and meeting the local goals. Stakeholders' participation is indispensable in

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Received 18 October 2015
Accepted 22 May 2016

order to incorporate their views for the successful planning and implementation of adaptation measures. The current practice in most of the LDCs lack not only a systematic prioritization approach but also the absence of stakeholders' participation, which could facilitate in informed decisions.

This research aims to provide an integrated assessment framework for the adaptation measures to reduce the vulnerability to climate change. The assessment framework has been applied and tested at the Eastern fringe of Dhaka city which is highly vulnerable to flooding. Based on the assessment and analysis, potential adaptive measures have been identified for more effective action taking into account the existing limitations.

1.1. Adaptation assessment

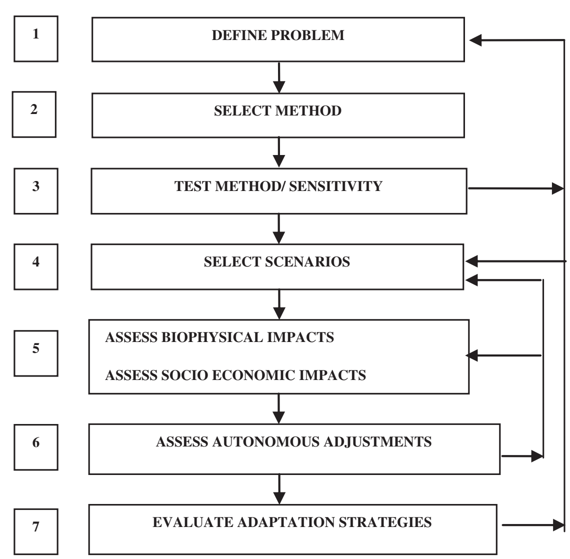
Adaptation to climate change involves the alteration of the affected system (natural or human) in response to the climatic events (observed or future) and their impacts (Olmos, 2001). This alteration or adjustment can be of, for instance, processes, practices, built environment, social phenomena etc. Intergovernmental Panel on Climate Change (IPCC) Third assessment report (IPCC, 2001) has defined adaptation to climate change as, 'Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'. 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). Although it seems to be clear on paper it is not in practice, because 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. United Nations Development Program (UNDP) and United Nations Framework Convention on Climate Change (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 1).

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. United Nations Development Programme (UNDP) (2001) came up with an Adaptation Policy Framework (APF) which consists of five steps (Figure 2). 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.

APF establishes a link between climate change adaptation and sustainable development and global environmental issues. 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.

However, it possesses some limitations. Although 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



Source: Carter et al. 1994

Figure 1. The seven steps of climate impact assessment.

DOI: 10.1002/mcda

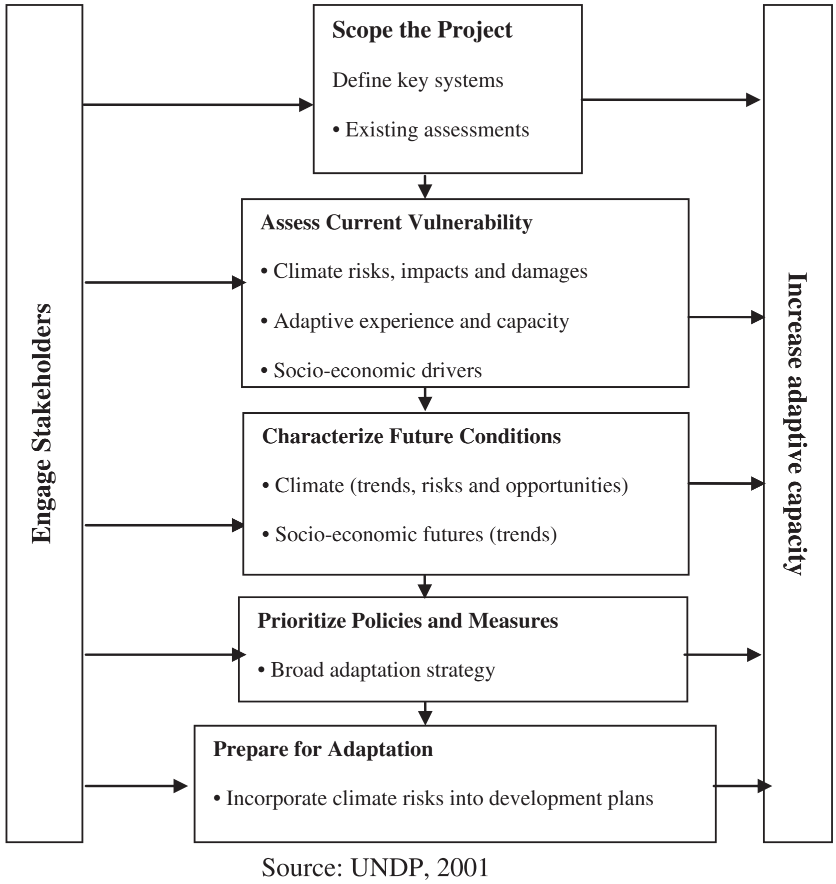


Figure 2. The adaptation policy framework or ‘second generation’ framework.

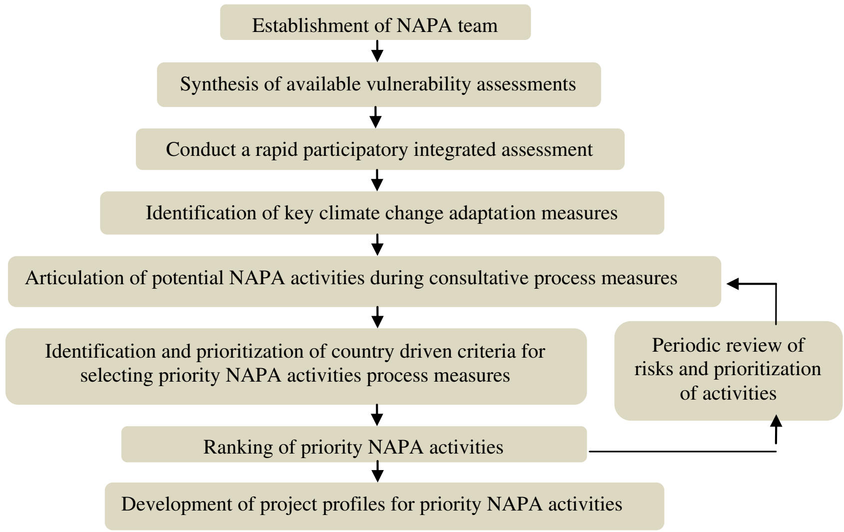
strategies will be distributed among the stakeholders. Another drawback is that the stakeholders are assumed to be known beforehand and therefore it does not show how to spot them. Each stage is dependent on various data, whereas the task to acquire data in LDC is not an easy job.

A major move by the UNFCCC was to facilitate the LDCs 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 (United Nations Framework Convention on Climate Change (UNFCCC), 2002).

‘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’ (United Nations Framework Convention on Climate Change (UNFCCC), 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 (United Nations Framework Convention on 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. 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 (Figure 3).

DOI: 10.1002/mcda



Source: Annotated guidelines for the preparation of National Adaptat ion Programs of Action, 2002

Figure 3. Flowchart of main steps in developing a NAPA.

1.2. Prioritization of adaptation measures

There are various approaches in practice for adaptation assessment where the most commonly used techniques are Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA) and Multi-Criteria Analysis (MCA) (Figure 4).

1.2.1. CBA. This is used when efficiency is the only criterion (UNFCCC, 2011). Hence it calculates the costs and benefits for all the options and compares them which assist in identifying the most efficient option. But here lies the limitation of this approach as it relies on only one criterion and it can only assess if all are expressed in monetary terms.

1.2.2. CEA. It is used to identify the adaptation option which is least costly for meeting specific goals. It is primarily applied when it is difficult to express all the benefits of adaptation measures in monetary terms but where the cost can be quantified (UNFCCC, 2011). Thus, it allows one to identify the option which can achieve a defined goal in the most cost effective way. But the limitation of this approach is it cannot consider the other dimensions, e.g. co-benefits, equity, feasibility.

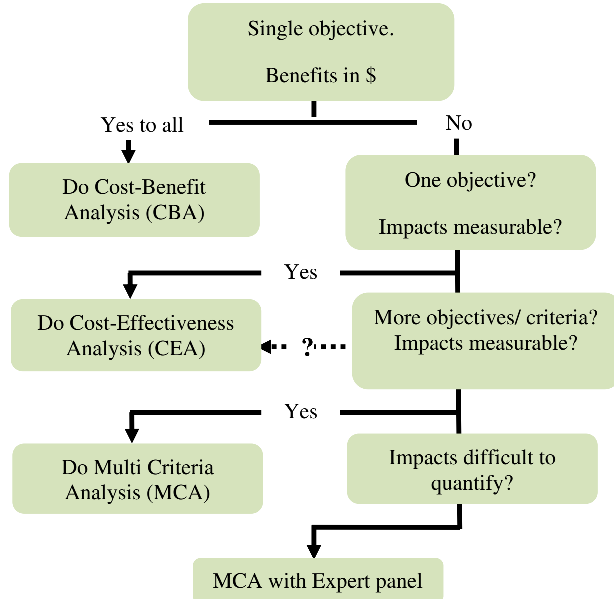
1.2.3. MCA. Involves assessment of adaptation options based on certain criteria. These criteria can be both quantitative and qualitative. Thus it can accommodate both types not being restricted like CBA or CEA. Moreover, it allows a participatory process for the assessment, i.e. all the stakeholders can participate at different stages of assessment.

The above discussion suggests that MCA, as an approach for adaptation assessment, brings the most advantages.

1.3. MCA

Brooks *et al*. (2009) defines MCA as, '*any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives*' (Brooks *et al*., 2009, p 46). Desirable objectives and indicators which correspond to the options to be assessed must be identified for conducting this method. The indicators/criteria can be both qualitative and quantitative; there can be indicators like costs expressing in monetary terms, at the same time, qualitative indicators like social indicators. Numerous assessments require both types of indicators to be considered at the same platform, i.e. environmental impact assessment and policy decisions. MCA can handle varied range of indicators/criteria for comparing different options, i.e. social, environmental, technical, economic and financial criteria. The key significance of this approach lies in its participatory aspect. It allows participation of stakeholders in the assessment process, i.e. identifying the assessment criteria and weighting of those criteria.

DOI: 10.1002/mcda



Note: Benefits in $ means Benefits can be quantified and expressed in monetary units
Source: UNFCCC, 2002

Figure 4. What method to use?

1.4. Why apply MCA for climate adaptation assessment?

There are certain assumptions as per UNFCCC (United Nations Framework Convention on Climate Change (UNFCCC), 2002) for evaluating climate adaptation measures:

a Diverse criteria and indicators have to be taken into account;
b In many cases, it is not possible to evaluate climate change costs in monetary terms
c Often there is a lack of data to conduct CBA or CEA
d The perspectives of local people must be considered as they are the most affected
e The adaptation responses, which have been assessed based on participation of all the relevant stakeholders in the decision making, are most acceptable.

All the above assumptions are catered for by one methodology, that is, MCA. For this reason, the United Nations advocates MCA as the preferred method to assess adaptation options and policies. Moreover, environmental problems are characteristically complex in nature, uncertain and multiple scales are involved, and have their impacts on varied ranges of people and organizations. Therefore, the assessment of climate adaptation measures should be participatory involving all the stakeholders in the decision making process.

Haque *et al.* (2012) refer to examples of successful application of MCA method all over the world; urban flood risk assessment in Germany (Kubal *et al.*, 2009), ranking of adaptation options for climate change for the Netherlands (Bruin *et al.*, 2009), decision making process for policy planning in Canada (Qin *et al.*, 2008), assessing flood risks and identify flood vulnerable areas by incorporating GIS in Nigeria (Yahaya *et al.*, 2009) and more on.

2. METHODOLOGY

Deriving from the aforementioned discussion, in this research adaptation assessment is conducted based on MCA which allows both normative judgement and technical expertise in the assessment process. The framework is inspired by the NAPA guidelines for LDC. The NAPA process uses the MCA method to allow the LDC 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.

DOI: 10.1002/mcda

This analytical method of MCA is assisted by an Excel based software tool, namely Climate Actions Prioritization (CLIMACT Prio) Decision Support Tool.

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

Step 1 Selection of potential adaptation options based on the problem

At first, adaptation options are selected for assessment. In many cases, step 1 may be revisited, specifically in those cases where there is a lack of acceptable alternatives (Greening and Bernow, 2004).

Step 2 Stakeholders' objectives and indicators selection

The next step involves deciding on how to compare different options' contribution to meet the underlying objectives. To serve this, criteria are selected to identify the performances of the options in meeting the objectives. To derive on the criteria, stakeholders' perspective may be important. They can be directly involved in some or all stages of the process. Another approach of deriving the criteria can be through analysing relevant secondary documents. Criteria must fulfil some qualitative attributes as described by Hajkowicz *et al*. (2000) and Belton and Stewart (2002). These are value relevance, operationality, reliability, measurability, decomposability, non-redundancy, preferential independence and completeness. Both the process of defining criteria and a poorly defined criterion can lead to potential biases in the subsequent judgements of performance and weights.

Step 3 Experts' judgements: Assessment of adaptation options

The next step is to score each adaptation option against specific criteria. This step allows the evaluation of tradeoffs of candidate options between the criteria (Hobbs and Meier, 2000). It is done by the experts' judgement. This step ensures the inclusion of technical expertise in the assessment process. A numerical score is assigned to each option for each criterion considering the expected consequences. Ideally the scores portray how much the experts are willing to accept for the tradeoffs among the criteria. This step is subjected to various biases, for instance, framing effects. The experts' decisions are often influenced by the response format (Guinto, 2008). Hence, it needs to be carefully designed to avoid potential biases that could alter the ranking of options.

Step 4 Standardization of criteria values

Normalization or standardization of criteria values is conducted to avoid the influence of different dimensions of criteria and different measurement scales on the results of ranking. In this step, the initial measured values of the criteria are converted to non-dimensional relative values, with proportionality of values remaining unchanged. (Zavadskas *et al*., 2006).

Step 5 Stakeholders' focus group discussion on weighting of indicators

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. The formula for estimating the criteria weights is:

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

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 6 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 and 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:

$$FS_j = \sum WS_{ji},$$

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

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Step 7 Sensitivity analysis

Sensitivity analysis is conducted to investigate how sensitive the result is to the variables. It is a way to incorporate the uncertainty and range of stakeholders' preferences.

3. CASE STUDY: DHAKA, BANGLADESH

Dhaka, the capital of Bangladesh, is one of the fastest growing mega cities in the world. According to the 1974 census, the population was 1.6 million. But now, according to the most recent census of 2011, it has reached 12.04 million. The population density of the city is considered to be the highest in the world. It is particularly vulnerable because of its unplanned urbanization being located in a country like Bangladesh where storms and floods are regular events. According to Maplecroft Climate Change Vulnerability Index 2013 (Maplecroft, 2013), Dhaka has been identified as the most vulnerable city to Climate Change. Although flooding has a long history in the country and the city, it is projected to be further exacerbated by climate change, i.e. erratic and heavy rainfall, river flow changes caused by sea level change. The location of the city also intensifies its risks to flooding as it is located in the central area of the flat deltaic plain of the GBM basin (Bala *et al*., 2010). Moreover, it is situated in the active river tidal zone which holds up water in low lying areas during high tides (Haque *et al*., 2012) (Figures 5 and 6).

Flooding is a common scenario for the city and occurs almost every year with varied intensity leading to economic, environmental and livelihood damages. The area of the city at highest risk to flood is the Dhaka East, which is predominantly a low lying area. It is at risk not only because of its topography but also it is completely unprotected from flooding. Essentially these low lying areas and water bodies in Dhaka East function as water retention areas to store the excess water from the storm runoff. Thus it contributes to the sustainability of the natural ecosystem as well. Conventionally, these water retention areas have been storing the excess water and draining to the adjacent river through the connected canals. Therefore, while the natural drainage is performing well, there is no water logging. But over the recent years, a dramatic change has been occurring and these water retention areas are decreasing at an alarming rate. The primary reason behind this is the rapid urbanization of the city. The population is increasing and there is land scarcity to house this increasing population. In consequence, the water retention areas are being encroached to meet the demand of the growing population. While the natural drainage is being damaged, the existing drainage infrastructure is not performing well because of poor maintenance and is in any case not adequate to meet the pace of the rapid urbanization. Hence, the population of Dhaka east is suffering from inundation.

3.1. Proposed adaptation measures

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. The interventions that have been proposed according to technical considerations of the project includes Flood embankment, Pumping stations, Regulators/sluices, Retention basins, Construction and upgrading of road network, Flood walls and Canal improvement. 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 even after seventeen years since the project was approved, although successive governments have declared it to be a priority project.

3.2. MCA application for flood adaptation assessment for Dhaka East

Step 1 All the above mentioned existing proposed adaptation options have been selected for assessment. Two other options, 'Early warning system' and 'Enhancing the emergency response mechanism', have been proposed for assessment by studying case studies bearing similar context.

Developing countries have limited capacity and resources to adapt to climatic hazards. Therefore, while selecting adaptation options for developing countries, this has to be kept in mind. The case study of Jamaica[1] states a vivid example how developing countries can successfully adapt to climatic hazards by reducing the amount of damage. It shows early warning system as an adaptation option for low cost flood hazard management with an organized and structured institutional arrangement.

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

DOI: 10.1002/mcda

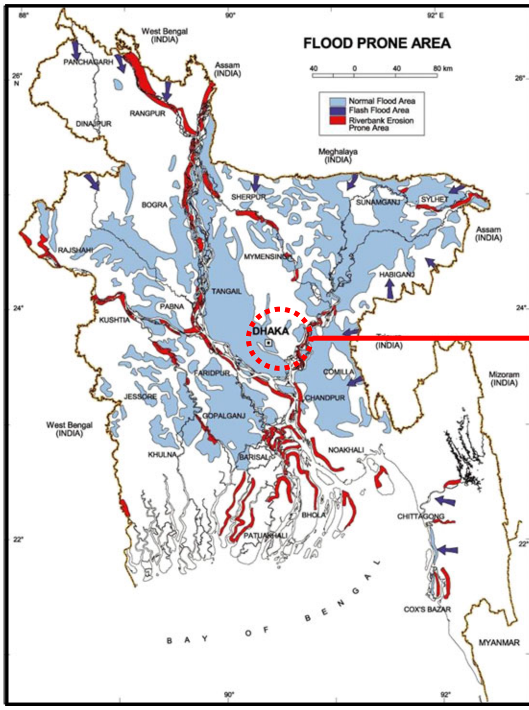

Figure 5. Flood prone areas of Bangladesh.

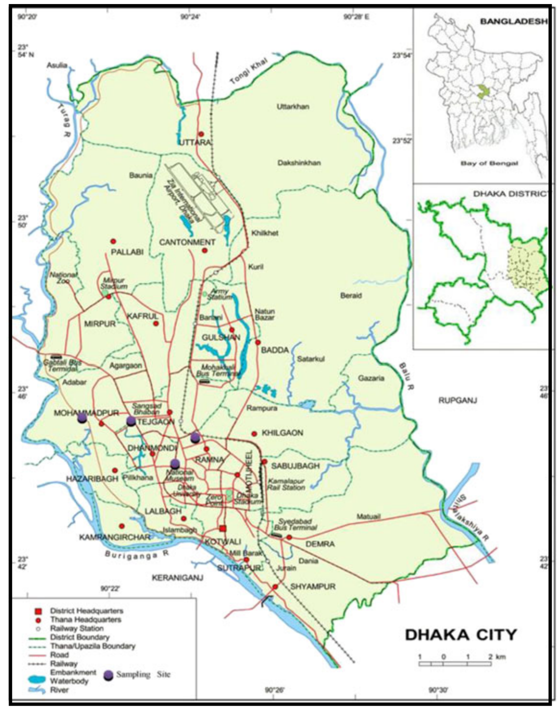

Figure 6. Dhaka city (blow up).

Emergency preparedness mechanism is crucial for any flood management plan to reduce the damage of life and habitat. But in the developing world, most of the countries posses a severe backlog in the use of efficient tools to enhance emergency preparedness mechanism. The primary reason behind it is financial capacity and skilled manpower. The case study of Allahabad city, India[2] shows the importance of investing in technology which in turn can reduce the damages caused by flood which is far higher than the initial investment.

The present status of early warning system in Dhaka is found to be significantly poor. The principal institution responsible for this is 'Flood Forecasting and Warning Center' (FFWC). FFWC does not have enough stations to measure the river water level and is highly dependent on meteorological department for rainfall data. Moreover, the dissemination of flood warning is also very poor. There is lack of co ordination among the related institutions. This option is expected to be very useful for reducing the damage because during the field work, 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.

'Disaster Management Bureau', the principal institution dealing with emergency response to flooding in Bangladesh, has very limited activity in Dhaka. Coastal areas and the areas prone to flash floods are mostly its functioning areas, having no flood shelters in Dhaka. It is the school and other educational buildings, which are converted to flood shelter during flood hazards. Therefore, enhancing the emergency response mechanism is highly needed for Dhaka, specifically for Dhaka East which is more prone to flood.

Considering the above discussion, 'Early warning system' and 'Enhancing the emergency response mechanism' have been proposed as additional options for assessment along with the existing proposed options by the Government to protect the study area from flood.

Step 2 The criteria for assessing the adaptation measures 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.

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

DOI: 10.1002/mcda

Potential stakeholders were selected by purposive sampling. Community representatives represented the most affected communities of the study area, representatives from the small business and farmers' community have also been represented, three most vulnerable infrastructure sectors (Road, Sanitation and sewage, Water supply) have been taken into account and also the non governmental organization (NGO) dealing with social and development objectives of the study area are represented in the stakeholder group.

Focus group discussion (FGD) was conducted with the stakeholder group in order to identify the criteria to be considered during adaptation assessment. 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 (Tables I and II) 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.

Step 3 Scoring of each adaptation option based on the criteria is performed by selected experts. Sample expert respondents are selected by using purposive sampling method based on predefined criteria. The criteria were expertise in the climate change adaptation and flood management sector, i.e. vulnerability assessment, impact assessment, adaptation assessment and flood management. An advantage of snowball sampling has been taken as it arose during the in depth interview.

Secondary data has been used for the criterion 'cost' (Table III). Because the selected experts have expertise in different fields related to flooding and all of them have experience working on the study area, it is expected that their point of view for scoring has covered the major concerns which should be considered during assessing adaptation options in the studied context. To avoid potential biasness, the

Table I. List of selected criteria and indicators

Category of criteria	Indicators	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 and technological	Institutional and technical capacity	″1–5″	Min

Table II. 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

DOI: 10.1002/mcda

scoring has been done independently by the experts (i.e. each expert scored separately without consulting with each other) and the final score was identified by making average of the scores given by them for each option based on each criterion.

Table III has been formulated by making average of scores given by the experts for each option against specific criterion.

Step 4 Standardization of criteria values

Table III uses different scales and units to score the criteria, i.e. percentage, millions, numeric scale of 1–5. Therefore, all the scores are being standardized to a common scale. Table IV shows all the standardized scores. Here the scale of ‘0 to 1’ has been used for standardization. For

Table III. 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

Table IV. Standardized scores[1]

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

[1]The standardization of scores and all calculations have been performed with the aid of the Excel based software tool, namely Climate Actions Prioritization (CLIMACT Prio) Decision Support Tool.

example, the criteria ‘Employment generation’ uses a 1 to 5 scale.

$$1 \rightarrow 5 \text{ (Observed scale)}$$
$$0 \rightarrow 1 \text{ (Standardized scale)}$$

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

$$64.27 \leftarrow 0.75 \text{ (Observed scale)}$$
$$0 \leftarrow 1 \text{ (Standardized scale)}$$

Step 5 Weighting of each selected criterion is done based on a second round of a FGD with the stakeholder group. 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. The stakeholders were 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 stakeholders had to choose a specific importance level and one of the values assigned for that importance level, for instance, they have to choose a value either 90 or 100 for importance level ‘Very high’. The final weight of each criterion is based on the importance and value data decided by the stakeholder group as consensus. 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 V and Figure 7 show the outcome (consensus) of the second FGD.

Step 6 The scores given by the experts are combined with the weights decided by the stakeholders in order to get the weighted scores (Table VI).

Prioritization of adaptation options is done based on the final weighted scores per option (Table VII).

From Figure 8, it is vivid that the top three priorities for adaptation options are: protection of water retention areas, enhancing early warning system and canal improvement.

Step 7 Sensitivity analysis

Fourteen scenarios have been considered to perform the sensitivity analysis. Scenarios 1 to 7 show change in variable weight by 20 units and scenarios 8 to 14 show 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 9).

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

Table V. 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 and technological	Institutional and technical capacity	3	″1–5″	Low	40	9.1%

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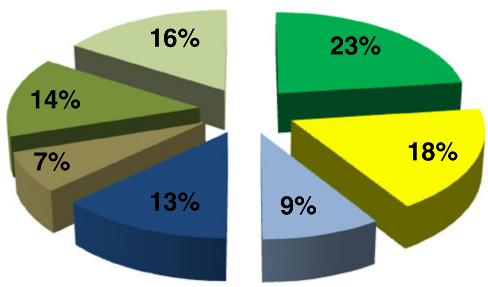

Figure 7. Criteria weights.

Table VI. 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

Table VII. 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

4. DISCUSSION

The list of criteria to be considered during the adaptation assessment process has been significant finding which was because of the stakeholders' direct involvement. These have resulted from discussions which limit the risk of institutional or personal bias. Because the stakeholder group includes representatives from various groups, the identified criteria encompass a range of perceptions from different categories of people.

The final outcome of the research is the ranking of the adaptation options. The ranking shows protection

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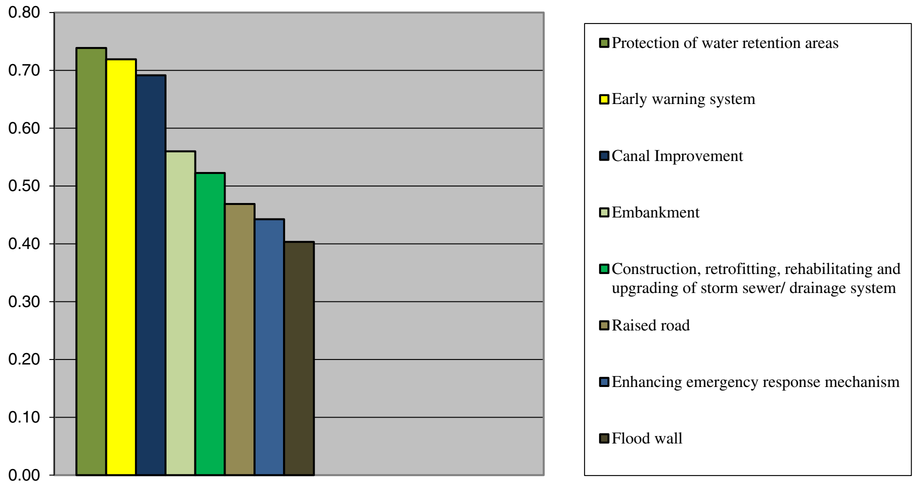

Figure 8. Ranking of adaptation options.

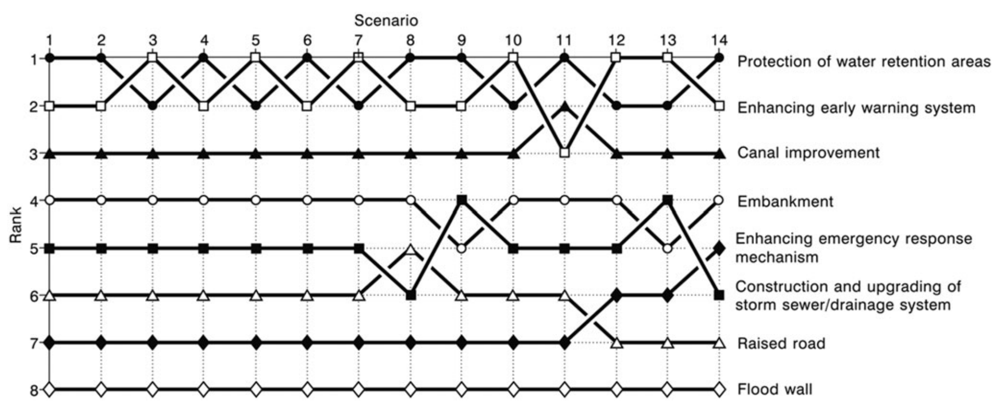

Figure 9. Sensitivity analysis.

of the water retention area, enhancing early warning systems and canal improvements to be the most effective. But in the context of Dhaka, the construction and up gradation of drainage system are being most talked about in the flood management sector for reducing flood vulnerability. Apparently if the drainage system is improved, it is expected to reduce flooding, but for a least developed country there are other factors that should also be considered, i.e. budget and technical capacity. Construction and up gradation of the drainage system require high budget and 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. This is an eye opener for the implementing organizations of the country.

Uncertainty of stakeholders' preferences has also been incorporated by performing a sensitivity analysis. It shows that that the results are quite robust with regard to changes of the criteria weights, which further confirms that the highest ranked measures performed well for most of the criteria.

4.1. Implications of the study

The current study has methodological implications for adaptation assessment in the LDC context. 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 in a

DOI: 10.1002/mcda

structured way within a developing countries' context on an urban scale. This methodology not only ensures transparency and multidimensionality by considering multiple criteria and multiple stakeholders' preferences but also includes experts' judgements.

It has assisted certain policy oriented and decision making related implications. For instance, the criteria for the assessment of the adaptation options and their importance level that has been identified through the MCA ensure a participatory approach incorporating the stakeholders' preferences. The stakeholder group includes representatives from root levels as well whose preferences are often neglected during the decision making process in the context. Therefore, the decision makers can learn about their preferences and consider those during the decision making process.

As mentioned earlier, in a developing country context it is difficult to implement all the planned adaptation measures at the same time. Hence the MCA approach helps to prioritize the planned options as per their efficacy considering all the existing limitations and constraints. For instance, protection of water retention areas has shown to be the most effective measures to be undertaken for the study area considering the limitation of cost, institutional and technical capacity.

4.2. Limitations of MCA

There is a prerequisite to conduct MCA and that is, the stakeholders participating in the process have to agree on the overall objective of the research. The process can be often very lengthy and iterative considering the prolonged negotiation period. And also, there is often a risk of interdependency among the identified criteria (Brooks *et al*., 2009). This selection of criteria is not straightforward; usually those which can be easily attributed are selected.

5. CONCLUSION

Regardless of all the uncertainties about the future climate change, it is certain that the impact of climate change will be exacerbated in the developing world. In the era of climate change, the frequency and intensity of extreme climatic events will be higher. But whether these events turn into disaster depends on the coordinated preparation and management.

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 is very high.

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

An effective prioritization of adaptation measures to be implemented is an exigent task. In this research, this task has been conducted considering all the major constraints and limitations. It has incorporated both subjective (experts' scoring) and objective (actual cost) information. Furthermore, inclusion of all the relevant stakeholders has been ensured during the decision making process which ascertains the outcome to be more legitimate. On top of that, the entire process of adaptation assessment through the MCA approach provides a platform for knowledge generation by incorporating both experts and the stakeholders, which enormously helps the decision making process.

5.1. Scope for further research

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 etc 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 CEA.

Climate change poses comprehensive risks of flooding which is not always possible to take into account within the application of the MCA method (Haque *et al*., 2012). These comprehensive risks are likely to be considered by a broader decision making process like risk management. Therefore, MCA cannot be a standalone tool for identifying and prioritizing the adaptation options, but it can certainly generate information regarding the relative merits for the options under consideration. Climate change is a sensitive sector involving multiple risks. Therefore, a wider MCA assessment process incorporating the risk management can be a direction for further research.

DOI: 10.1002/mcda

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