Integrated Flood Risk Management using Multi Criterion Decision Analysis- Acase study of Bihar

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ABSTRACT: Floods are the most recurring hazard in Kosi and Gandak river basin of North Bihar in eastern India. Despite a long history of flood control measures in the state for more than six decades, the rivers still continues to cause a huge disaster and a lot of misery in the region due to extensive flooding. The Kosi and Gandak River typically shows very high discharge variability in addition to high sediment flux from upper part of catchment. This often results to inundation followed by flooding in the low-lying tracts of the alluvial plains. This paper re-visits the flooding issue in Kosi and Gandak river basin and presents an in-depth analysis of flood management.This flood risk analysis follows multiple criteria decision analysis (MCDA) using Concept of Choosing by Advantage (CBA) for selecting component of Integrated Flood Risk Management (IFRM) by stakeholder and decision makers.

Keywords: Floods, MCDA, CBA, IFRM

1.0 INTRODUCTION: Flooding as mentioned effects on infrastructure, environment and economic activity including agriculture. A risk manager or stake holder providing flood management service is most concerned that a flood is predicted, appropriate warnings are dispersed and acted upon. whereas as a risk manager or stake holder who is responsible for construction of embankment or flood protection structure is concerned with timely completion of work, appropriate site selection, its effectiveness and many more aspects. Likewise for risk manager dealing with different component of IFRM hasdifferent prime concern. Benefit-cost analysis is still used as a convenient mechanism for comparing options, but its potential shortcomings are always there.

In this paper IFRM has been advocated for protection from flood. The key approaches which are component of IFRM arei) Flood Policy and Strategy Development ii) Vulnerability Analysis, Risk Modelling and Mapping iii) Flood Data and Information Management iv) Flood Early Warning Systems v) Flood Infrastructure Concepts vi) Ecosystem-based Approaches for Flood Management vii) Emergency Planning and Response. As far as selection of a particular component (alternative) or its prioritization for a particular risk manager or risk event is concerned where alternatives of IFRM depends on various factors. MCDA can be used to select a particular alternative by analysis of various factor on which it depends. Study of flood is very complex and number of techniques has been suggested by various research scholars for MCDA. In order to implement IFRM, It is desired to select its alternative depending on various factors. For that one should use MCDA. In this study we have adopted CBA method.

There is plethora of published literature on MCDAsuch as (Bana E Costa 1990; Zimmermann &Gutsche 1991; Vincke 1992; Munda 1995; Belton & Stewart 2002). Most of these textbooks deals with mathematical aspect of MCDA like the decision rules, various approaches and methods like MAUT, Outranking and AHP etc. In his book- Decisions with Multiple Objectives Preferences and Value Trade-Offs, Keeney &Raiffa (1993) focus on the MAUT approach. On other hand Drechsler (1999; see also Klauer et al. 2006) focus on extensions of the Preference Ranking Organization Method for Enrichment Evaluations approach.

From the literature it appears to be assumed that all MCDA methods are equal or that the differences between them does not matter, and it is left to the user to select any one. But actually methods matter. In CBA valuing the importance of advantages between various alternatives makes this method viable. Methods that rank factors or values, such as value-based methods, require a high level abstraction, inducing unanchored conflicting questions. And hence CBA methods are superior to other methods for making sustainability decisions.

2.0 STUDY AREA

As a case study for Implementation of IFRM we have selected Kosi and Gandak river basin (Figure 1) which extend from mountainous region of China, Nepal upto plains of plains of northern Bihar, India.

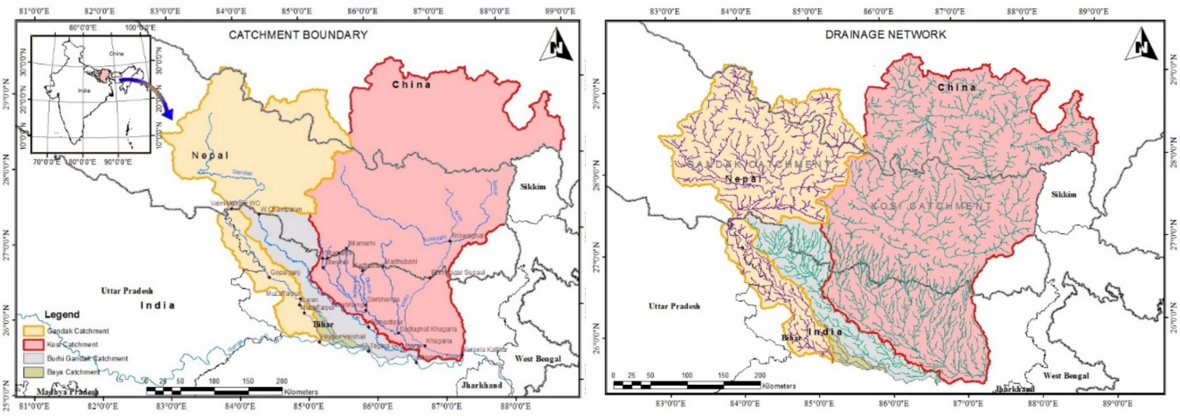

Fig.1:Index map and Drainage map of Study area

River floods are one of the most common natural disasters in South Asian Countries. India, Bangladesh and China top the list of people across the world worst affected by river flooding. Huge drainage area of rivers as been depicted by drain lines on study area (Figure 1) where about 5, 3.5 and 3.3 million people are exposed every year, respectively. The potential national economic consequence of river floods is highest in India which has by far the most GDP exposed at □13,000 million. India as a country faces more potential change in exposed GDP than any other country and could increase more than 10-fold to 2030. The major flood prone areas of India cover almost 13.63 % area of the country. The chronic flood prone basins are Ganga and Brahmaputra covering northern and north-eastern parts of the country. The five most flood prone states are Uttar Pradesh (U.P.), Bihar, West Bengal (WB), Assam and Odisha (Gupta, Javed, &Datt, 2003).

3.0 CONCEPT OF CBA AND APPLICATION EXAMPLE

CBA is a sound system to make decisions using well-defined vocabulary to ensure clarity and transparency in the decision-making process (Parrish and Tommelein, 2009). In order to explain how CBA tabular method can be used for MCDA, a very simple example from AEC industry is being discussed. For simplicity we are comparing only two alternatives: (1) standard wall construction and (2) double stud wall construction.

In this example we considered the following factors and criteria: (1) Thermal Control and the criterion for selection is 'higher Thermal Control is the better'. (2) Durability and the criterion for selection is 'the building must last 50 years.' (3) Buildability refers to how easy it is to build the wall assembly. The criterion for selection is 'the easier to build, the better.' (4) Material use and the criterion for selection is 'the less material used the better.'

Step1: Alternatives are identified which likely yield important advantages over other alternatives.
Standard wall construction and Double stud wall construction

Step2: Factors are defined with the purpose of differentiating between alternatives. In CBA that factor is identified which will reveal significant differences among alternatives.
Thermal *Control, Durability, Buildabilityand Material use*

Step3: Criteria for Selection is decided as following.
Higher Thermal Control (R-value) is the better, Building must last 50 years, Easier to build is the better and Less material used is the better

Step4: Summaries the attribute of each alternative by making research in a Table 1.

Table1. Research table with attribute of each alternative

Factor	Alternative 1 Standard wall construction	Alternative 2 Double stud wall construction
Thermal Control	R-10	R-15
Durability	Depend on exterior barrier	Depend on exterior barrier
Buildability	Easy to Construct	Requires skill
Material use	Framing lumber could be minimized	Wall framing material is increased significantly

Step5: Identify lowest preferred attribute of every factor and decide on the advantage of each alternative's attribute relative to least preferred factor (Table 2).

Table2. Research table with advantage of each alternative

Factor	Alternative 1 Standard wall construction	Alternative 2 Double stud wall construction

Thermal Control	R-10		R-15	
Higher R- value is the better	Adv.:	Imp.	Adv.: Higher R-Value by 5	Imp.
Durability	Depend on exterior barrier		Depend on exterior barrier	
Building must last 50 years	Adv.:	Imp.	Adv.:	Imp.
Buildability	Easy to Construct		Requires skill	
Easier to build is the better	Adv.: Easy to build	Imp.	Adv.:	Imp.
Material use	Framing lumber could be minimized		Wall framing material is increased significantly	
Less material used is the better	Adv.: Lesser material	Imp.	Adv.:	Imp.

Step6: Decide on the importance of advantage by selecting paramount advantage, which is most among all. Paramount advantage is used as anchoring point to weight other advantage by making comparison and then the importance of advantage is summed up for each alternative (Table 3).

Table3. Final table

Factor	Alternative 1 Standard wall construction		Alternative 2 Double stud wall construction	
Thermal Control	R-10		R-15	
Higher R- value is the better	Adv.:	Imp.	Adv.: Higher R-Value by 5	Imp.: 70
Durability	Depend on exterior barrier		Depend on exterior barrier	
Building must last 50 years	Adv.:	Imp.	Adv.:	Imp.
Buildability	Easy to Construct		Requires skill	
Easier to build is the better	Adv.: Easy to build	Imp.: 30	Adv.:	Imp.
Material use	Framing lumber could be minimized		Wall framing material is increased significantly	
Less material used is the better	Adv.: Lesser material	Imp.: 50	Adv.:	Imp.

Step7: Now the importance of advantage is compared and best alternative is selected which is in turn compared with cost separately. In this case Alternative1 Standard wall construction has 80 importance of advantage, which is more than Alternative 2 Double stud wall construction. Hence Alternative1 is selected by CBA.

4.0 DESCRIPTION OF CASE STUDY

Bihar is India's most flood-prone State, with 76% of the population, in the north Bihar living under the recurring threat of flood devastation from River Kosi, Gandak and some other small rivers. About 6.880 million hectares of land out of about 9.416 million hectare comprising 73.06 %is flood affected in state of Bihar. Salient features of study area have been mentioned in table 4.Community needs related to floods in Bihar are diverse as physical and socio-cultural characteristics are bound to vary from basin to basin. Even within each basin the needs and problems of local communities differ between the upper, middle and downstream parts.

Table 4: Silent features of Kosi and Gandak River basin

	Gandak	**Kosi**
Length	630 km India–300 km (approx.)	720 km india–260km, Nepal-50km
Catchment Area	46,300(in km^2) China – 5687, Nepal – 30882 Bihar – 7288, UP – 1874	74,500(in km^2) China – 35567, Nepal – 27863 Bihar – 11070
Discharge (m^3/s)	1529(Av. Annual)	2,236(Av. Annual)
	12500(Bankful discharge)	6615(Bankful discharge)
	18116(Observed max discharge) on 31st July 2003	12043(Observed max discharge) on 5th oct 1967
	27294(Probable max flood)	23153(Probable max flood)

In Bihar most of the floodplain agriculture, which is a key livelihood for millions, consists of rain fed (Kharif) cropsare vulnerable to flood in case of heavy monsoon rain. Flood waters often stay for more than a week in agricultural fields affecting crop yield. Long duration flood also affects fodder which on its turn is impacting livestock. In many places heavy floods also cause sand deposition on fields making it unsuitable for agriculture. Post-flood environmental and health issues were found to be also a serious problem in the basins. Poor sanitation and environmental conditions are causing a high incidence of water borne and vector borne diseases during and after the peak floods have receded. All the river basins lack adequate flood shelter facilities and godowns for storing food and seeds for communities. For shelter the communities resort to schools, community halls, terraces of pucca houses, and even roads and embankments.

IFRM is discussed for sustainable solution for this problem which aims at sustainable development,maximizing net benefits from floodplains, minimizing loss of lifein particular through end-to-end preparedness planning for extreme events and environmental preservation.

5.0 COMPONENTS INVOLVED IN IFRM

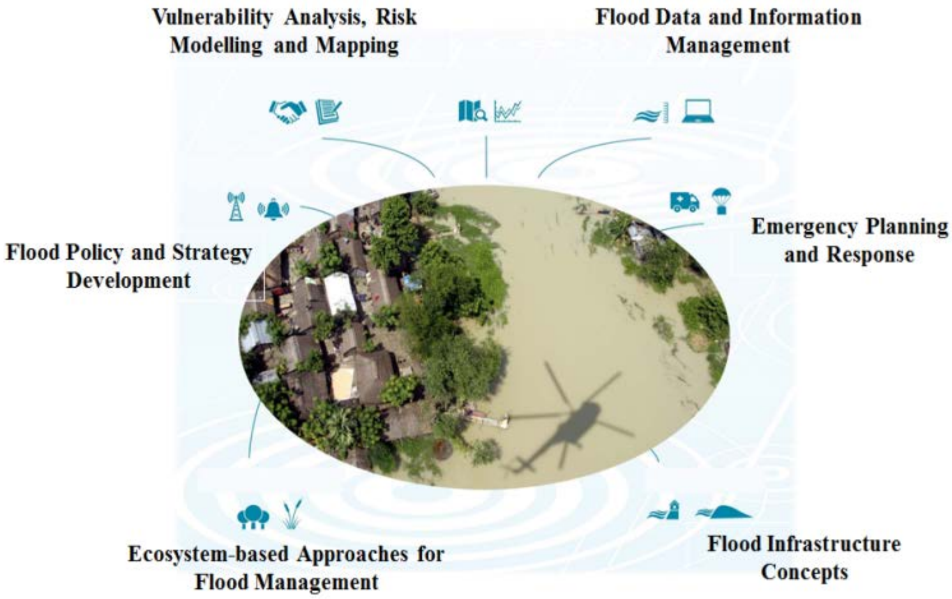

Figure 3. Components of IFRM

5.1 Flood Policy and Strategy Development

Suggestion for Institutional Development for better policy and strategy against flood in Bihar like Institutional coordination by developing Standard Operation Procedures (SOP), Organizational strengthening and Capacity building / training in IFRM

5.2 Vulnerability Analysis, Risk Modelling and Mapping

Flood Risk Modelling and Mapping which can be undertaken in Bihar such as River Modelling, Breach Assessment, Overtopping Analysis, and Surface Water Runoff Calculations.

5.3 Flood Data and Information Management

Supporting the implementation and maintenance of hydrometric networks and hydrodynamic models, including flood scenario development and forecasting.Assessing the interaction of land use change and hydrology in combination with climatic as well as regional and national studies. Developing human and institutional capacities to improve inter-sectorial communication and supporting the implementation of shared information platforms.

5.4 Flood Early Warning Systems

The gauge-to -gauge relationship has a limitation of waiting till the flood is observed at the base station upstream of the forecasting station. Therefore in the process, the possible lead time from the catchment lag up to the base station is lost. Such lead time can be easily added by introducing a hydrological model that can transform the observed rainfall into a simulated hydrograph at the base station. Thus there is a need for improving the lead time, forecasting river flow at any site along the river, and mapping like inundation from the forecasted flood at community level for effective flood response.

5.5 Flood Infrastructure Concepts

Suggestion for Flood mitigation Infrastructure development for Bihar which includes improvement of lead time for flood early warning and warning message dissemination mechanism. Review of the reservoir operation rules for enhanced flood cushioning (15% of live storage is recommended). Up gradation of embankments up to required safety level. Improvement of rural drainage to reduce water logging problem and improvement of flood cushioning in the basin. Improvement of urban drainage as an integrated approach while town planning.

5.6 Ecosystem-based Approaches for Flood Management

Through their natural processes such as infiltration, evapotranspiration and the storage of surface and ground water in lakes and aquifers, ecosystems provide valuable flood management services to both urban and rural environments. Vegetated buffer zones, for example, can reduce runoff whilst wetlands can act as temporary storage reservoirs.

5.7 Emergency Planning and Response

As part of comprehensive disaster risk management and in order to enhance capacities of national partner institutions, local communities and the private sector for post flood situations, following services should be implemented to strengthen capacities for emergency planning and response. Like, Development of communication materials and training in order to build capacity for the public sensitization and education on behavior and measures in emergency cases. Contingency planning, including the development and testing of appropriate standard operating and evacuation procedures.Establishment of communication channels for a quick and efficient flow of information in case of emergency between institutions. Clarification and functional distribution of tasks and competences amongst stakeholders at all levels.Integration of disaster risk management into urban development plans. And also, post disaster needs assessments.

6.0 APPLICATION OF CBA

Table 5. Calculation Sheet of CBA table

Alternatives → / Factors ↓	Alternative 1			Alternative 2			Alternative 3			Alternative 4			Alternative 5			Alternative 6			Alternative 7			Weightage to Factor
	Flood Policy and Strategy Development			Vulnerability Analysis, Risk Modelling and Mapping			Flood Data and Information Management			Flood Early Warning Systems			Flood Infrastructure Concepts			Ecosystem-based Approaches for Flood Management			Emergency Planning and Response.			
	Rank	Advantage	Importance	Rank	Advantage	Importance	Rank	Advantage	Importance	Rank	Advantage	Importance	Rank	Advantage	Importance	Rank	Advantage	Importance	Rank	Advantage	Importance	
Investment	7	6	8.00	6	5	6.67	4	3	4.00	2	1	1.33	1	0	0.00	5	4	5.33	3	2	2.67	8
Time of implementation	5	4	7.20	6	5	9.00	3	2	3.60	2	1	1.80	4	3	5.40	1	0	0.00				9
Reliability	4	3	5.00	3	2	3.33	2	1	1.67	6	5	8.33	5	4	6.67	1	0	0.00	7	6	10.0	10
Work force required	4	3	2.50	6	5	4.17	7	6	5.00	3	2	1.67	2	1	0.83	5	4	3.33	1	0	0.00	5
Monitoring	4	3	3.00	6	5	5.00	7	6	6.00	3	2	2.00	2	1	1.00	5	4	4.00	1	0	0.00	6
Reachability to remotest	1	0	0.00	6	5	1.67	5	4	1.33	7	6	2.00	3	2	0.67	4	3	1.00	2	1	0.33	2
Community participation	1	0	0.00				2	1	0.75	5	4	3.00				3	2	1.50	4	3	2.25	3
Skill required	1	0	0.00	2	1	0.17	3	2	0.33	5	4	0.67	6	5	0.83	7	6	1.00	4	3	0.50	1
Costly Instruments req.				4	3	2.40	5	4	3.20	1	0	0.00	3	2	1.60	6	5	4.00	2	1	0.80	4
Maintenance required	7	6	7.00	6	5	5.83	5	4	4.67	3	2	2.33	2	1	1.17	4	3	3.50	1	0	0.00	7
Communication	4	3	4.00	1	0	0.00	5	4	5.33	2	1	1.33	6	5	6.67	3	2	2.67	7	6	8.00	8
TOTAL		28	36.70		36	38.23		37	35.88		28	24		24	24.83		33	26.33		22	24.55	

In IFRM Seven numbers components are compared for the main advantages of each alternative in step by step process. In step 1, identify the alternatives likely to yield advantage over other alternatives which in case of IFRM are seven components as mentioned above. In step 2, define factors with the purpose of differentiating between alternatives which has been mentioned in first column of the table 5. In CBA it's important to identify which factor will give significant differences between all alternatives. In step 3, Criteria for judging is decided like higher is better or lesser is better etc. In step 4, all attributes or characteristics of each alternative is summarized. Step5, Least preferred attribute of each factor is identified and the advantage of each alternative's attribute relative to least preferred one is decided. Importance of advantage is decided by selecting paramount advantage, which is most among all. Paramount advantage is used as anchoring point to weight other advantage by making comparison and then the importance of advantage is summed up for each alternative. Step 7, now the importance of advantage is compared and best alternative is selected which is in turn compared with cost separately. For different components of IFRM sustainable alternative is selected by CBA as tabulated above.

7.0 RESULT

In Table 5, the importance of advantage is tabulated for each alternatives. Importance of all factors for every alternative is summed up. For different components of IFRM sustainable alternative is selected by CBA for maximum importance. In this case study of IFRM in Bihar the component which may be chosen by advantage is "Vulnerability Analysis, Risk Modelling and Mapping" i.e. alternative having overall maximum importance of 38.23.CBA methods are superior to value-based methods of MCDA when selecting a sustainable component of IFRM. CBA helps stakeholders to make decisions based on relevant facts minimizing conflict. In contrast, other methods, which ask stakeholders to weigh factors, may not focus to the same extent on the importance of the advantages between attributes of alternatives, and therefore stakeholders may have difficulties in resolving conflicting interests and collaborating. Methods that weight factors are not taking decisions based on the relevant facts, therefore they should be more likely to produce wrong decisions. Consequently causing worse environmental, social and economic impacts of the Flood irrespective of the management adopted.

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