Study on Mitigation Measures of Gumti Hydro Power Plant Using Analytic Hierarchy Process and Concordance Analysis Techniques

K. Majumdar, S. Datta

***Abstract*—**Electricity is recognized as fundamental to industrialization and improving the quality of life of the people. Harnessing the immense untapped hydropower potential in Tripura region opens avenues for growth and provides an opportunity to improve the well-being of the people of the region, while making substantial contribution to the national economy. Gumti hydro power plant generates power to mitigate the crisis of power in Tripura, India. The first unit of hydro power plant (5MW) was commissioned in June 1976 & another two units of 5 MW was commissioned simultaneously. But out of 15MW capacity at present only 8MW-9MW power is produced from Gumti hydro power plant during rainy season. But during lean season the production reduces to 0.5MW due to shortage of water. Now, it is essential to implement some mitigation measures so that the further atrocities can be prevented and originality will be possible to restore. The decision making ability of the Analytic Hierarchy Process (AHP) and Concordance Analysis Techniques (CAT) are utilized to identify the better decision or solution to the present problem. Some related attributes are identified by the method of surveying within the experts and the available reports and literatures. Similar criteria are removed and ultimately seven relevant ones are identified. All the attributes are compared with each other and rated accordingly to their importance over the other with the help of Pair wise Comparison Matrix. In the present investigation different mitigation measures are identified and compared to find the best suitable alternative which can solve the present uncertainties involving the existence of the Gumti Hydro Power Plant.

***Keywords*—**Concordance Analysis Techniques, Analytic Hierarchy Process, Hydro Power.

I. Introduction

HYDRO power plants convert potential energy of water into electrical energy. The basic principle of hydro power is that if water can be channelized from higher level to lower level than the resulting potential energy of water can be used to do work. Hydro power is a very clean source of energy and only uses the water, the water after generating electrical power, is available for other purposes like drinking water, irrigation etc. Traditionally it is cheap and clean source of electricity. Electricity plays an important role in the development of civilization of a country. The performance of all important sectors in the economy ranging from agriculture to commerce and industry as also the performance of social sectors like health depends largely on the availability, cost and quality of power. The development in power sector in Tripura despite geographical, economic and infrastructural hindrance has come a long way till now, but hydro power generation is not progressed properly.

Gumti is one of the larger rivers in Tripura, India which flow west ward and discharges into Bangladesh. Due to the construction of a dam for hydropower plant a large reservoir is created which is known as Gumti reservoir. This reservoir is at upper catchment of Gumti River. The storage capacity of reservoir is 23570 Hectare metre. The submerged area at F.R.L of 92.05m and M.W.L. of 95.25m was found to be respectively 46.34 and 74.86sqkm. With the help of this reservoir, Gumti Hydro Power plant generates power to mitigate the crisis of power in Tripura. Design capacity of this Hydro Power Plant was 15 MW. It has 3 unit(s). The first & 2^{nd} units were commissioned in 1976 and the last in 1984. But out of 15MW capacity at present only 8MW-9MW power is produced from Gumti hydro power plant during rainy season. But during lean season the production reduces to 0.5MW. The present work wants to investigate the level of impact of climate change on availability of water in the Gumti reservoir through which hydro power is being generated using Artificial Neural Network under different climate change scenarios. Now, it is essential to implement some mitigation measures so that the further atrocities can be prevented and originality will be possible to restore. In this regard the present investigation utilized the advancement of the Analytic Hierarchy Process (AHP) and Concordance Analysis Techniques to identify the better alternative among the available options of mitigation.

II. Literature Review

The AHP and its use of pair wise comparisons have inspired the creation of many other decision-making methods. Besides its wide acceptance, it also created some considerable criticism; both for theoretical and for practical reasons. Since the early days it became apparent that there are some problems with the way pair wise comparisons are used and the way the AHP evaluates alternatives [1]. It is observed that the AHP may reverse the ranking of the alternatives when an alternative identical to one of the already existing alternatives is introduced [2]. In order to overcome this deficiency, Belton and Gear proposed that each column of the AHP decision matrix to be divided by the maximum entry of that column.

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Thus, they introduced a variant of the original AHP, called the revised-AHP. Later, it is accepted the previous variant of the AHP and now it is called the Ideal Mode AHP [3]. Besides the revised-AHP, other authors also introduced other variants of the original AHP. However, the AHP (in the original or in the ideal mode) is the most widely accepted method and is considered by many as the most reliable Multi-criteria decision-making (MCDM) method.

The fact that rank reversal also occurs in the AHP when near copies are considered, has also been studied [4]. Few study provided some axioms and guidelines on how close a near copy can be to an original alternative without causing a rank reversal [5]-[7]. It is suggested that the decision maker has to eliminate alternatives from consideration that score within 10 percent of another alternative. This recommendation was later sharply criticized by Dyer [8].

III. Scope and Objective of This Study

The objective of the present investigation is to predict selection of mitigation measures to sustain the plant feasibility by adopting the required cognitive decision making approaches. The advantages of capabilities of Analytical Hierarchy Process and Concordance Analysis Techniques are utilized in respectively predicting the impact of uncertainty and selection of suitable mitigation measure for environmental as well as socio-economical sustenance of the plant.

IV. Methodology

The decision making ability of the AHP and CAT are utilized to identify the better decision or solution to the present problem. In the present investigation different mitigation measures are identified and compared to find the best suitable alternative which can solve the present uncertainties involving the existence of the Gumti Hydro Power Plant. Some related criteria are identified by the method of surveying within the experts and the available reports and literatures. Similar criteria are removed and ultimately seven relevant ones are identified. All the criteria are compared with each other and rated accordingly to their importance over the other with the help of a scale of comparison known as Pair wise Comparison Matrix as given below.

1	Objectives i and j are of equal importance
3	Objectives i is weakly more important than j
5	Objectives i is strongly more important than j
7	Objectives i is very strongly more important than j
9	Objectives i is absolutely more important than j
2,4,6,8	Intermediate values

The values are normalized by dividing the rating by the sum of the columns. Then average of each row is taken as the weightage of those particular criteria.

Steps of Decision Making with the help of AHP

- Determination of Decision Objective
- Collection of Criteria
- Selection of Relevant and Uncommon Criteria
- Rating of Criteria with the help of Pair wise Scale of Importance
- Normalization of Each Rating
- Average of Each Row as the Weightage of the Criteria represented by that row.

Concordance Analysis Techniques (CAT) is one of the multi-criteria assessment tools in which alternative plans are ranked by a series of pair wise comparisons across a set of objectives in a rank-ordering technique [9]. In the current study, the Attributes are *IDFC, IDVC, SEB, EB, SHE, TH, EH* and objectives are five mitigation measures. The analysis is based on the project effects matrix, which contains a vector of scores for each alternative on each of the chosen objective measures. Two different indices are calculated from the project effects matrix: A concordance index calculates the degree to which one alternative plan is preferred to another for a given weighting structure on the objectives. Dominance indices are developed from the concordance scores, and are used to establish the relative preference of each alternative with respect to the given weighting scheme.

V. Result and Discussion

The criteria for identification of the optimal mitigation measure among the available options are selected as follows:

A. *Infrastructure Development Fixed Cost (IDFC)*

This criterion depicts the amount of fixed cost that will be incurred for development of infrastructures if a certain mitigation measure is decided to be adopted.

B. *Infrastructure Development Variable Cost (IDVC)*

This criterion depicts the amount of variable cost that will be incurred for development of infrastructures if a certain mitigation measure is decided to be adopted.

C. *Socio-Economic Benefits (SEB)*

This criterion shows the Socio-Economic benefits that may be created when a certain mitigation measure is decided to be implemented. The domain of Socio-Economic benefits may include increase in income of the local people, creation of various opportunities to earn additional income etc.

D. *Environmental Benefits (EB)*

Environmental benefits will include the up gradation and conservation of the natural landscape and resources of the region.

E. *Probability of Socio-Economic Hazards (SEH)*

This criterion will represent the hazards or uncertainty or negative impact that may be aggravated due to the implementation of a certain mitigation measure.

F. *Probability of Environmental Hazards (EH)*

This criterion will show the degradation of natural resources and landscaped due to the introduction of certain mitigation alternatives.

G.Probability of Technical Hazards (TH)

The mitigation measure to be adopted must be technically feasible and should not compromise the existing technical supremacies. These criteria will depict the technical hazards or compromises that may be required to be adopted for the implementation of certain mitigation option.

TABLE I
THE NORMALIZED RATING VALUES OF DIFFERENT ATTRIBUTES

	IDFC	IDVC	SEB	EB	SEH	EH	TH	Weightage (Wa)
IDFC	X	0.778	0.556	0.444	0.556	0.556	0.222	0.444
IDVC	1.286	X	0.714	0.571	0.714	0.714	0.286	0.612
SEB	1.800	1.400	X	0.800	1.000	1.000	0.400	0.914
EB	2.250	1.750	1.250	X	1.250	1.250	0.500	1.179
SEH	1.800	1.400	1.000	0.800	X	1.000	0.400	0.914
EH	1.800	1.400	1.000	0.800	1.000	X	0.400	0.914
TH	4.500	3.500	2.500	2.000	2.500	2.500	X	2.500

TABLE II
THE NORMALIZED RATING VALUES OF DIFFERENT MITIGATION MEASURES WITH RESPECT TO IDFC

IDFC	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	1.125	1.125	0.875	0.625	0.750
M_2	0.889	X	1.000	0.778	0.556	0.644
M_3	0.889	1.000	X	0.778	0.556	0.644
M_4	1.143	1.286	1.286	X	0.714	0.886
M_5	1.600	1.800	1.800	1.400	X	1.320

TABLE III
THE NORMALIZED RATING VALUES OF DIFFERENT MITIGATION MEASURES WITH RESPECT TO IDVC

IDVC	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	2.000	4.500	3.500	2.000	2.400
M_2	0.500	X	2.250	1.750	1.000	1.100
M_3	0.222	0.444	X	0.778	0.444	0.378
M_4	0.286	0.571	1.286	X	0.571	0.543
M_5	0.500	1.000	2.250	1.750	X	1.100

TABLE IV
THE NORMALIZED RATING VALUES OF DIFFERENT MITIGATION MEASURES WITH RESPECT TO SEB

SEB	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	0.875	1.000	1.000	0.750	0.725
M_2	1.143	X	1.143	1.143	0.857	0.857
M_3	1.000	0.875	X	1.000	0.750	0.725
M_4	1.000	0.875	1.000	X	0.750	0.725
M_5	1.333	1.167	1.333	1.333	X	1.033

TABLE V
THE NORMALIZED RATING VALUES OF DIFFERENT MITIGATION MEASURES WITH RESPECT TO EB

EB	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	1.000	0.667	0.500	0.500	0.533
M_2	1.000	X	0.667	0.500	0.500	0.533
M_3	1.500	1.500	X	0.750	0.750	0.900
M_4	2.000	2.000	1.333	X	1.000	1.267
M_5	2.000	2.000	1.333	1.000	X	1.267

TABLE VI
THE NORMALIZED RATING VALUES OF DIFFERENT MITIGATION MEASURES WITH RESPECT TO SEH

SEH	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	1.000	2.000	1.000	1.000	1.000
M_2	1.000	X	2.000	1.000	1.000	1.000
M_3	0.500	0.500	X	0.500	0.500	0.400
M_4	1.000	1.000	2.000	X	1.000	1.000
M_5	1.000	1.000	2.000	1.000	X	1.000

TABLE VII
THE NORMALIZED RATING VALUES OF DIFFERENT MITIGATION MEASURES WITH RESPECT TO EH

EH	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	1.000	1.500	1.000	1.500	1.000
M_2	1.000	X	1.500	1.000	1.500	1.000
M_3	0.667	0.667	X	0.667	1.000	0.600
M_4	1.000	1.000	1.500	X	1.500	1.000
M_5	0.667	0.667	1.000	0.667	X	0.600

TABLE VIII
THE NORMALIZED RATING VALUES OF DIFFERENT MITIGATION MEASURES WITH RESPECT TO TH

TH	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	0.600	1.200	1.200	1.200	0.840
M_2	1.667	X	2.000	2.000	2.000	1.533
M_3	0.833	0.500	X	1.000	1.000	0.667
M_4	0.833	0.500	1.000	X	1.000	0.667
M_5	0.833	0.500	1.000	1.000	X	0.667

TABLE IX
THE MATRIX FOR DECIDING THE NORMALIZED WEIGHTAGE (NW) OF EACH OF THE MITIGATION MEASURES AND THEIR RANK

	IDFC	IDVC	SEB	EB	SEH	EH	TH	NW	RANK
Wa	0.444	0.612	0.914	1.179	0.914	0.914	2.5		
M_1	0.750	2.400	0.725	0.533	1.000	1.000	0.840	1.003	2
M_2	0.644	1.100	0.857	0.533	1.000	1.000	1.533	1.148	1
M_3	0.644	0.378	0.725	0.900	0.400	0.600	0.667	0.689	5
M_4	0.886	0.543	0.725	1.267	1.000	1.000	0.667	0.911	4
M_5	1.320	1.100	1.033	1.267	1.000	0.600	0.667	0.975	3

TABLE X
THE RATING OF DIFFERENT ATTRIBUTES WITH RESPECT TO MITIGATION MEASURES

	M1	M2	M3	M4	M5
IDFC	65	70	80	75	70
IDVC	60	70	40	15	10
SEB	High	V.high	good	Moderate	Moderate
EB	good	V.good	less	V.less	Moderate
SEH	Moderate	Moderate	High	High	Less
EH	Moderate	Moderate	Less	V.Less	Less
TH	High	V.High	Moderate	Moderate	Less

TABLE XI
THE WEIGHTAGES OF DIFFERENT ATTRIBUTES

Attributes	IDFC (A)	IDVC (B)	SEB (C)	EB (D)	SHE (E)	EH (F)	TH (G)
weightages	70	50	100	90	35	40	45

TABLE XII
THE MATRIX FOR DECIDING THE WEIGHTAGE OF EACH OF THE MITIGATION MEASURES AND THEIR RANK

	M1	M2	M3	M4	M5	Total	Rank
M1	X	E+F=75	B+C+D+F+G=325	B+C+D+F+G=325	B+C+D+E+F+G=360	1085	2nd
M2	A+B+C+D+E+F+G=430	X	B+C+D+F+G=325	B+C+D+F+G=325	A+B+C+D+E+F+G = 430	1510	1st
M3	A+E=105	A+E=105	X	A+B+C+D+E+F+G=430	A+B+C+E+F+G=340	980	3rd
M4	A+E=105	A+E=105	E+G=80	X	A+B+C+E+G=300	590	4th
M5	A=70	A=70	D+F=130	C+D+F=230	X	500	5th

After surveying throughout the literatures and consulting with the experts it is found that the following mitigation measures can be adopted to prevent the present degradation:

- Desiltation of the River Bed (M1) which confluents to form the Dumboor Lake. This measure will ensure steady flow of water from the rivers. This will also satisfy the increasing demand for water from the local inhabitants. The level of work involved to de-silt these two rivers is enormous and expensive. But adoption of such measures will ensure steady supply of water from the upstream.
- Desiltation of the Reservoir (M2) to increase depth of the same which in turn will also increase the storage capacity of the reservoir. This measure is economical but if the supply of water from the rivers decreases along with the

rainfall then the benefit from such activity will be uncertain.

- Installation of Micro Hydro Power Plant (M3) may be installed near by the existing plant to meet up the water availability during lean season.
- Implementation of Variable Head Turbines (M4) instead of the fixed head turbines which are in use now. This change will ensure plant capacity even at the time of water scarcity. The installation of such turbines is expensive but will ensure maximum utilization of the available resources.
- Installation of Surge tank (M5) which will hold the excess water and release the same when there will be scarcity in the resource. The implementation of a surge tank will ensure a steady flow of water within the penstocks to maintain the required kinetic energy for generation of power from the power plant. The cost of such installations is lesser than de-siltation activities but efficiency and capability of the same to satisfy the demand is doubtful.

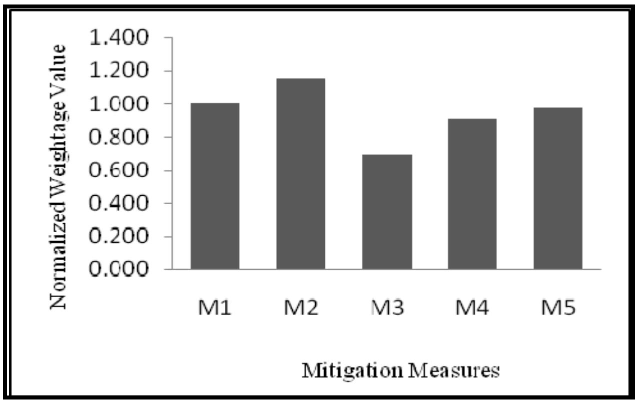

Fig. 1 Normalized Weightage (NW) of each of the Mitigation Measures as per Analytic Hierarchy Process

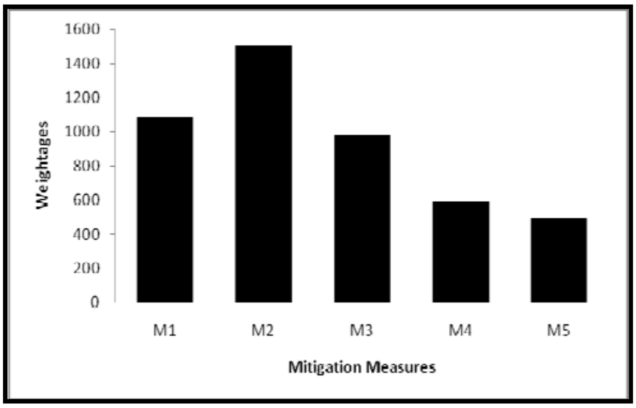

Fig. 2 Weightage of each of the Mitigation Measures as per Concordance Analysis Techniques

A. As per Analytic Hierarchy Process

Table I shows the Pair wise Ratings assigned to each of the attributes identified based on the literature survey and consultation with the experts. Tables II-VIII show the ratings of the different mitigation measures compared with each other with respect to each attributes considered for the study.

Ultimately the overall result from the decision making procedure is given in Table IX. From the decision it is observed that Mitigation measure No. 2 and No. 1 are the better alternatives for improvement of Gumti hydro power plant. All the mitigation measures can be considered rank wise viz. M2, M1, M5, M4, M3 (Fig. 1) and these measures can restore the hydro power plant to its original capacity.

B. As per Concordance Analysis Techniques

Table XI shows the Ratings of attributes with respect to mitigation measures based on the literature survey and consultation with the experts. The weights for different attributes put by a group of experts are also computed using another rating scale and these are showing in Table XII.

Ultimately the overall result from the decision making procedure is given in Table XII. From the decision it is observed that Mitigation measure No.2 and No.1 are the better alternatives for improvement of Gumti hydro power plant. All the mitigation measures can be considered rank wise viz. M2, M1, M3, M4, M5 (Fig. 2) and these measures can restore the hydro power plant to its original capacity.

VI. Conclusion

The present investigation tried to analyze the different mitigation measures and compared to find the best suitable alternative which can solve the present uncertainties involving the existence of the Gumti Hydro Power Plant. Out of 15MW capacity of Gumti hydro power plant, at present only 8MW-9MW power is produced during rainy season. But during lean season the production reduces to 0.5MW due to shortage of water. So, it will be essential to implement some mitigation measures so that the further atrocities can be prevented and originality will be possible to restore. In this regard the present investigation utilizes the advancement of the AHP & CAT to identify the better alternative among the 5(five) available options of mitigation. Some related attributes are identified by the method of surveying within the experts and the available reports and literatures. Similar criteria are removed and ultimately 7 (seven) relevant ones are identified. All the attributes are compared with each other and rated accordingly to their importance over the other with the help of Pair wise Comparison Matrix. From the Analytic Hierarchy Process (AHP) and Concordance Analysis Techniques (CAT) it is observed that Mitigation measure No.2 and No.1 are the better alternatives for improvement of Gumti hydro power plant. All the mitigation measures can be considered rank wise viz. M2, M1, M5, M4, M3 as per Analytic Hierarchy Process and viz. M2, M1, M3, M4, M5 as per Concordance Analysis Techniques. That is rank of M3, M4, M5 are not similar for Analytic Hierarchy Process and Concordance Analysis Techniques. But the rank of M1 and M2 are same in both the analysis. So from the decision it is clear that rank wise Mitigation measure No.2 and No.1 are the better alternatives for improvement of Gumti hydro power plant and these measures can restore the hydro power plant to its original capacity.

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