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Application of MCDM in Selection of Influential Water Quality Parameter in Location Selection of Hydropower Plant

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***Abstract*— The importance of hydro energy is also derived from its own source, which is water, an essential element of life. Therefore, from an ecological, economic, and sustainable development point of view, maintaining the quality of the water is of utmost importance. Water quality impacts dam operations, including temperature, dissolved oxygen, nutrient concentrations, and redox-sensitive metals. Seasonal variations in reservoir water quality also impact downstream conditions. Minimizing environmental impact and maintaining water parameters close to natural values is crucial for hydropower users. Supervising water quality is essential to prevent ecological degradation or implement necessary improvements. In these aspects the present study aims to identify the most influential water quality parameter in location selection of Hydropower plant. Two MCDM methods AHP and ANP has been applied to achieve the present objective. Nine parameters such as Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Phosphate (PO), Total Dissolved Solids (TDS), Chloride, Nitrate Nitrogen (NO_3 -N), Ammonia Nitrogen (NH_4 -N), Potential of Hydrogen (pH) and Temperature (T) have been chosen among the various parameters based on literature review and expert opinion to determine which one will carry the most weights as per the MCDM methods. The findings imply that, among the parameters chosen, the DO has the greatest impact on location selection of Hydropower Plant among the other parameters selected.**

***Index Terms*— Location selection, Hydro Power Plant, Water Quality, AHP, ANP**

I. Introduction

A hydropower plant, also known as a hydroelectric power plant, is a facility that generates electricity by harnessing the energy of flowing or falling water. It is one of the oldest and most widely used renewable energy sources in the world. Hydropower plants convert the kinetic and potential energy of water into mechanical energy, which is then converted into electrical energy through the use of turbines and generators. The amount of electricity a hydropower plant can generate depends on factors such as the flow rate of water, the height from which it falls, and the efficiency of the turbines and generators. Hydropower is considered a sustainable and renewable energy source because it relies on the natural water cycle and does not produce greenhouse gas emissions or air pollutants

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during electricity generation. However, the construction of large dams for hydropower can have environmental and social impacts, such as altering river ecosystems and displacing communities. As a result, there is ongoing debate about the trade-offs and sustainability of hydropower projects.

Water quality is the suitability of water for drinking, recreational uses, and as habitat for aquatic organisms and other wildlife. It is measured by the amount of sediment, water temperature, and concentration of chemical compounds, including nitrate-nitrogen and other nutrients in the water. Harvesting wood and development and use of infrastructure (roads, skid trails, and landings) can expose soil, leading to soil erosion and runoff that can affect water quality.

A. Literature Review

M.R.Singh et al. (2020) have conducted to assess the Water Quality Index (WQI) of the Doyang River from eight selected sampling stations. It points out that pH, DO and BOD played a central role in affecting the WQI of the river.

Alban Kuriqi et al. (2021) This reviews main objective is to provide an extensive overview of how changing the natural flow regime due to hydropower operation may affect various aspects of the fluvial ecosystem. interdisciplinary research progress involving different stakeholders is crucial to harmonize conflicting interests and enable the sustainable development of small run-of-river hydropower plants.

Avinash Kumar et al. (2021) The present observations contribute in the usefulness of these statistical methodologies to interpret and understand large dataset and also provide reliable information to reduce the tedious and cost of water quality monitoring and assessment programs.

Pelin Temel et al. (2023) The proposed approach allows the integration of ecological dimensions into the evaluation of RoR HEPPs through easy-to-measure indicators, among which environmental flow is a critical component.

Fida Ali et al. (2022) This study was aimed at identifying small run-of-river hydropower sites in Songkhla lake basin (SLB) Thailand. An integrated geographical information system (GIS), soil and water assessment tool (SWAT), and analytical hierarchy process (AHP) approaches were adopted to identify potential sites. The method adopted in this study can be applied in any other river basins around the world for sustainable hydropower potential assessment.

B. Objective & Novelty

Finding the most important water quality criterion while choosing a hydropower plant's location is the primary goal of this study. Two different MCDMs, namely AHP & ANP, have been used to accomplish the current goals. The most important water filter-related characteristics were determined using AHP in the study's initial phase. Next, ANP was used to determine which water quality characteristic was most important when choosing a location for a hydroelectric facility. The design and development of hydropower facilities is made easier by this study, which makes it significant.

C. METHOD USED

The present study was carried out to selection of most influential water quality parameter in hydroelectric site. To analyses the designing of water quality in this study was divided into the detailed methodology to obtain the objectives is explained below.

1. Aggregation Method: AHP & ANP

In the present study several MCDM methods were used to identify the priority parameter for decertification. The multi-criteria decision-making methods are also known as multi criteria decision analysis (MCDA) method that include for solving problems that have multiple criteria for choosing the best alternative among available number of a alternatives. The MCDM method is used in the present study are discussed below.

a. Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a multicriteria decision-making method that helps the decision-maker to solve a complex problem by converting it into hierarchy of sub-problems. The AHP MCDM method has limitations such that the value varies According to the form of hierarchy structure and it’s difficult to always maintain the consistency of responses. The ranking is given by using the value of some criteria, higher magnitude is ranked high and lower magnitude is ranked least and vice versa. This process of ranking maintains the consistency ratio within the limit automatically shows the decision hierarchy for the MCDM method.

Steps of the Analytical Hierarchy Process

1. Ranking of each selected alternatives based on the available data
2. Ranking of criteria on the basis of importance for the objective of study
3. Using Numerical Equivalent of Rank Pairwise Comparison of Criteria is made in the given equation

$$\text{Numerical Ranks (R)} = 1 - \frac{Rank\ of\ Criteria}{1+Number\ of\ Criteria} \tag{1}$$

4. Numerical equation of rank for alternatives are calculated using equation

$$\text{Numerical Ranks (R)} = 1 - \frac{Rank\ of\ Alternatives}{1+Number\ of\ Alternatives} \tag{2}$$

5. To estimate the Criteria weights value by comparing each criterion with each other criteria forming a comparison matrix using equation

$$C_{ij} = \frac{Ci}{Cj} \tag{3}$$

   Where C_{ij} represents the elements of the comparison matrix and C_i , C_j represents the numerical equivalent of rank of criteria.
6. To estimate the Criteria weights value by comparing each criterion with each other criteria forming a comparison matrix using equation

$$A_{ij} = \frac{Ai}{Aj} \tag{4}$$

Where A_{ij} represents the elements of the pairwise comparison matrix and A_i , A_j represents the numerical equivalent of rank of criteria.

b. Analytic Network process (ANP)

The Analytic Network Process (ANP) for decision-making with dependence and feedback is a comprehensive framework for the analysis of societal, governmental and corporate decisions. It is a process that allows one to include all the factors and criteria, tangible and intangible, which have a bearing on making a decision. The ANP allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback can capture the complex effects of interplay in human society, and this is especially important when risk and uncertainty are involved. Applying the ANP to a decision includes analysis of benefits, opportunities, costs and risks and combining their results by weighting them with respect to strategic criteria. A simple ANP model may consist of a single network, such as those used to estimate market share. But complex decisions invariably require the use of networks and sub-networks concerned with the following types of evaluation: a set of strategic criteria, in terms of which the outcomes to be described next are rated one at a time and the resulting weights used to synthesize these outcomes to determine the best one. Four major divisions follow this, each with several networks.

Steps of Analytical Network Process

i. To find the Criterion weighted value, the ANP MCDM followed the six steps of the AHP MCDM
ii. ANP then contrasts the requirements for alternatives. Each criterion therefore has a unique weight value.
iii. The final step computes row-wise averages by multiplying the criteria weights value by the alternative weights (calculated in the sixth step of AHP). By Normalizing the mean, find the updated relative weights of the alternatives.
iv. Repeat the AHP process with the updated criterion weight. If the difference between the existing weights and the new weights of the alternatives is grater than 0.0001, the ANP process is repeated, followed by the AHP process, until the difference between the new weight and the old weight value is less than 0.0001

II. METHODOLOGY

A. Selection of Criteria

The criteria selected in the objective depends on the data requirement for various parameter. Based on a literature review and experts view two criteria Cost and Efficiency were selected.

B. Selection of Alternatives

The selection of alternatives for the objective was based on a detailed review of literature in studies. It has been found that several indices are required for estimating potential of an area, the parameter required for estimating those indices are selected as alternatives. Among several parameters nine parameters were selected those are: Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Phosphate (PO), Total Dissolved Solids (TDS), Chloride, Nitrate Nitrogen (NO_3 -N), Ammonia Nitrogen (NH_4 -N), Potential of Hydrogen (pH), Temperature(T) based on data requirement.

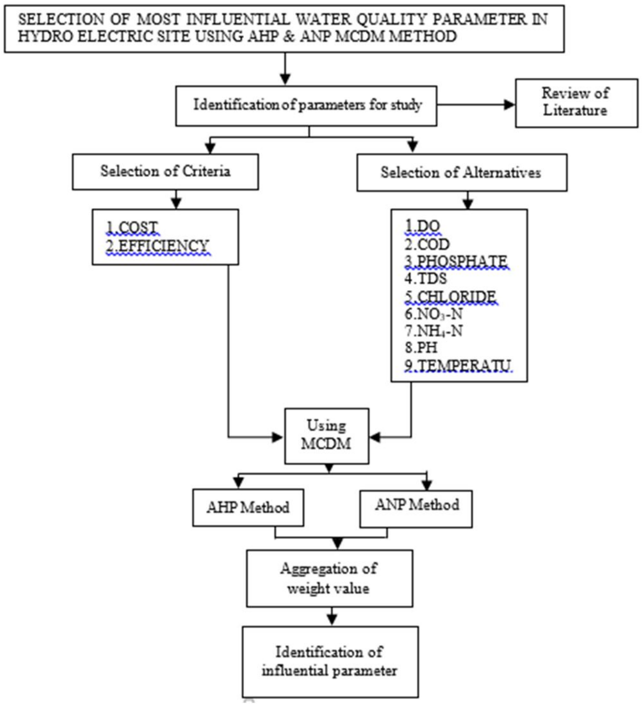

Figure 1: Flow chart of Methodology

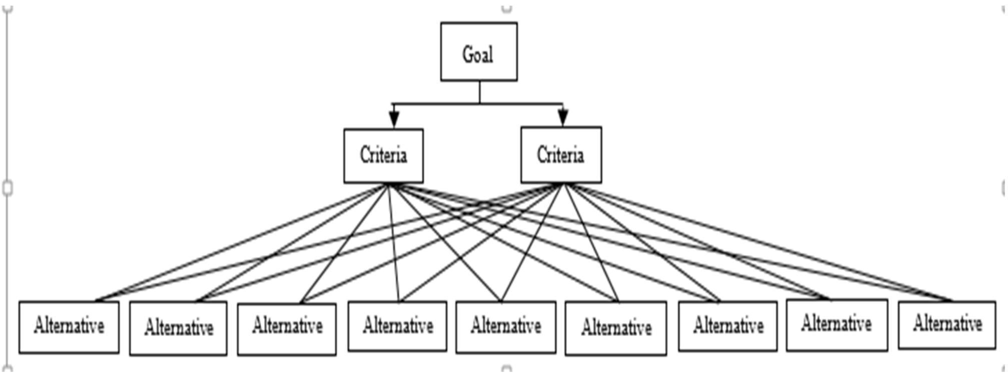

Figure 2: Hierarchy structure for AHP MCDM process

C. Identification of most significant Parameter

In the present study to achieve this objective two MCDM method AHP and ANP were used to identify the most influential parameter for study. In AHP and ANP method MCDM was used to estimate the criteria weightage and ranking the alternative. After selection of criteria and alternatives AHP MCDM method has been applied. AHP MCDM shows the weight valve of each of the selected parameters. Therefore, after determining the weighted value (WI) for all nine selected parameters. Now, in the second step of the study, ANP MCDM method has been used to identify the influencing parameters for water quality. Therefore, after determining the weighted value for all nine selected parameters.

III. Result & Discusion

A. Identification of Most Significant Parameter for Desertification

There were nine parameters selected for the study of desertification based on the literature review and experts view, from which one most significant parameter was required to be selected. The results for AHP and ANP hybrid MCDM methods are explained below

1. Analytical Hierarchy Process (AHP)

TABLE I: RANK WISE PARAMETER WITH RESPECT TO CRITERIA

SL. NO.	**PARAMETER**	**COST(RS)**	**EFFICIENCY (%)**
1	DO (mg/L)	7	8
2	COD (mg/L)	8	3
3	PHOSPHATE (mmol/L)	2	5
4	TDS (mg/L)	4	9
5	CHLORIDE (mg/L)	3	4
6	NO_3-N (µg/l)	1	1
7	NH_4-N (µg/l)	9	2
8	pH	6	7
9	TEMPERATURE (˚C)	5	6

TABLE II: COMPARE EACH CRITERIA WITH THE OTHER WITH RESPECT TO GOAL OF THE DECISION PROBLEM

	EFFICIENCY (%)	COST (RS)	GM	RW
EFFICIENCY (%)	1	2	1.41	0.667
COST (RS)	0.5	1	0.7	0.333
TOTAL			2.12	1

Rank of Criteria as per significance: Efficiency: 1st rank, Cost: 2nd rank

TABLE III: COMPARE EACH ALTERNATIVE WITH EACH ALTERNATIVE WITH RESPECT TO CRITERIA FOR COST

	NO_3-N	PHOSPHATE	CHLORIDE	TDS	TEMPERATURE	pH	DO	COD	NH_4-N	GM	RW
NO_3-N	1	1.12	1.28	1.5	1.8	2.25	3	4.5	9	2.17	0.2
PHOSPHATE	0.88	1	1.14	1.33	1.6	2	2.66	4	8	1.92	0.17
CHLORIDE	0.77	0.87	1	1.16	1.4	1.75	2.33	3.5	7	1.68	0.15
TDS	0.66	0.75	0.85	1	1.2	1.5	2	3	6	1.44	0.13
TEMPERATURE	0.55	0.62	0.71	0.83	1	1.25	1.66	2.5	5	1.20	0.11
pH	0.44	0.5	0.57	0.66	0.8	1	1.33	2	4	0.96	0.08
DO	0.33	0.37	0.42	0.5	0.6	0.75	1	1.5	3	0.72	0.06
COD	0.22	0.25	0.28	0.33	0.4	0.5	0.66	1	2	0.48	0.04
NH_4-N	0.11	0.12	0.14	0.16	0.2	0.25	0.33	0.5	1	0.24	0.02
										10.85	1

Table III. is showing the calculated values of geometric mean of each alternative with the help of AHP MCDM method

TABLE IV: COMPARE EACH ALTERNATIVE WITH EACH ALTERNATIVE WITH RESPECT TO CRITERIA FOR EFFICIENCY

	NO_3-N	NH_4-N	COD	CHLORIDE	PHOSPHATE	TEMPERATURE	pH	DO	TDS	GM	RW
NO_3-N	1	1.12	1.28	1.5	1.8	2.2	3	4.5	9	2.17	0.2
NH_4-N	0.88	1	1.14	1.33	1.6	2	2.66	4	8	1.92	0.17
COD	0.77	0.87	1	1.16	1.4	1.7	2.33	3.5	7	1.68	0.15
CHLORIDE	0.66	0.75	0.85	1	1.2	1.5	2	3	6	1.44	0.13
PHOSPHATE	0.55	0.62	0.71	0.83	1	1.2	1.66	2.5	5	1.20	0.11
TEMPERATURE	0.44	0.5	0.57	0.66	0.8	1	1.33	2	4	0.96	0.08
pH	0.33	0.37	0.42	0.5	0.6	0.7	1	1.5	3	0.72	0.06
DO	0.22	0.25	0.28	0.33	0.4	0.5	0.66	1	2	0.48	0.04
TDS	0.11	0.12	0.14	0.16	0.2	0.2	0.33	0.5	1	0.24	0.02
TOTAL										10.85	1

Table IV. is showing the calculated values of geometric mean of each alternative with the help of AHP MCDM method

TABLE V: MULTIPLY THE WEIGHTAGE OF THE CRITERIA WITH THE WEIGHTAGE OF THE ALTERNATIVE

	COST	EFFICIENCY	SUM	RW	RANK
DO	0.02	0.02	0.05	0.05	9
COD	0.01	0.10	0.11	0.11	4
PHOSPHATE	0.05	0.07	0.13	0.09	8
TDS	0.04	0.01	0.05	0.10	7
CHLORIDE	0.05	0.08	0.14	0.11	6
NO_3-N	0.06	0.13	0.20	0.11	5
NH_4-N	0.007	0.11	0.12	0.12	3
pH	0.02	0.04	0.07	0.13	2
TEMPERATURE	0.03	0.05	0.09	0.14	1
			1.00		

Table V. showing multiply the weightage of the criteria with the weightage of the alternative for that criteria and calculate the row wise average. Here the least parameter of among this is DO of value 0.05 and the highest parameter is TEMPERATURE of value 0.14

2. Analytical Network Process (ANP)

Table VI. showing multiply the weightage of the criteria with the weightage of the alternative for that criteria and calculate the row wise average

TABLE VI: MULTIPLY THE WEIGHTAGE OF THE CRITERIA WITH THE WEIGHTAGE OF THE ALTERNATIVE

	COST	EFFICIENCY	SUM	RW
DO	0.02	0.02	0.05	0.05
COD	0.01	0.10	0.11	0.11
PHOSPHATE	0.05	0.07	0.13	0.09
TDS	0.04	0.01	0.05	0.10
CHLORIDE	0.05	0.08	0.14	0.11
NO_3-N	0.06	0.13	0.20	0.11
NH_4-N	0.007	0.11	0.12	0.12
pH	0.02	0.04	0.07	0.13
TEMPERATURE	0.03	0.05	0.09	0.14
			1.00	

TABLE VII: MULTIPLY THE WEIGHTAGE OF ALTERNATIVES WITH THE WEIGHTAGE OF THE CRITERIA FOR THAT ALTERNATIVE AND AVERAGE TO FIND THE UPDATED WEIGHTS OF CRITERIA

	DO	CO D	PHOSPH ATE	TDS	CHLO RIDE	NO_3- N	NH_4- N	pH	TEMPERAT URE	AVERAGE	NORMALI ZED AVARAG E
COST	0.03	0.0 7	0.06	0.06	0.07	0.07	0.08	0.0 8	0.09	0.07	0.66
EFFICIE NCY	0.01	0.0 3	0.03	0.03	0.03	0.03	0.04	0.0 4	0.04	0.03	0.33

Table VII. shows the importance depicted in the last column shows the updated weights of the criteria. The entire process is repeated with the updated weights of criteria. If the difference between the existing weights of the alternatives and new weightage if alternatives is more than 0.0001

TABLE VIII: MULTIPLY THE WEIGHTAGE OF ALTERNATIVES WITH THE WEIGHTAGE OF THE CRITERIA FOR THAT ALTERNATIVE AND AVERAGE. NORMALIZE THE AVERAGE TO FIND THE UPDATED WEIGHTS OF CRITERIA

PARAMETER	COST (RS)	EFFICIENCY (%)	SUM	Rank
DO (mg/L)	0.344	0.017	0.362	1
TEMPERATURE (˚C)	0.093	0.046	0.141	2
pH	0.089	0.044	0.133	3
NH_4-N (µg/L)	0.084	0.041	0.126	4
NO_3-N (µg/L)	0.079	0.039	0.119	5
COD (mg/L)	0.079	0.039	0.119	6
CHLORIDE (mg/L)	0.074	0.036	0.111	7
TDS (mg/L)	0.069	0.034	0.104	8
PHOSPHATE (mmol/L)	0.064	0.032	0.096	9

After finding all the parameters from Table 8 by applying AHP and ANP method we get the least and the highest parameter of water quality:
Here the least parameter of among this is PHOSPHATE of value 0.096 and the highest parameter is DO of value 0.362

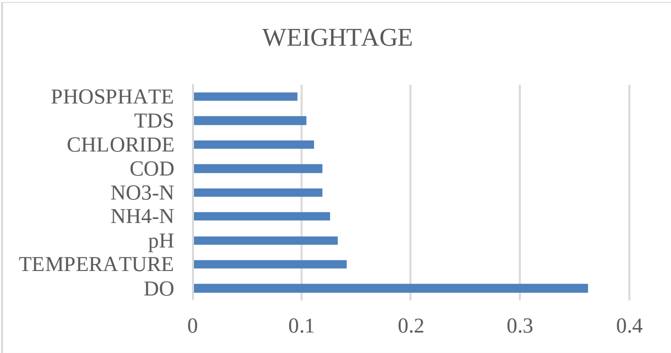

Figure 3: Graphical representation of ranking of configuration for water quality

IV. Conclusion

The aim of this study to achieve the objective the present study used the MCDM method namely AHP and ANP. Nine parameters have been chosen for this investigation based on literature review. Nine parameters such as Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Phosphate (PO), Total Dissolved Solids (TDS), Chloride, Nitrate Nitrogen (NO_3 -N), Ammonia Nitrogen (NH_4 -N), Potential of Hydrogen (pH) and Temperature (T) have been chosen among the various parameters based on literature review and expert opinion to determine which one will carry the most weights as per the MCDM methods. The findings imply that, among the parameters chosen, for AHP the least parameter of among this is DO of value 0.05 and the highest parameter is TEMPERATURE of value 0.14 and for ANP the difference between the existing weights of the alternatives and new weightage if alternatives is more than 0.0001 After finding all the parameters from Table VIII by applying AHP and ANP method we get the least and the highest parameter of water quality: Here the least parameter of among this is PHOSPHATE of value 0.096 and the highest parameter is DO of value 0.362

Abbreviation

MCDM: Multi Criteria Decision Making
AHP: Analytical Hierarchy process
ANP: Analytical Network Process
pH: Potential Hydrogen
DO: Dissolved Oxygen
COD: Chemical Oxygen Demand
PO: Phosphate
TDS: Total Dissolved Solids
T: Temperature
MCDA: Multi Criteria Decision Analysis
WI: Weighted Value

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