International Research Journal of Applied and Basic Sciences
© 2013 Available online at www.irjabs.com
ISSN 2251-838X / Vol, 4 (12):3633-3640
Science Explorer Publications

Identification of the keycharacteristicsandcriteria for designing of damsandhydroelectric power plantsand their evaluationusingAHP (Case studyof the Gardalan damandpower plantin Iran- Kurdistan in Iwpco.)

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ABSTRACT: Due to need to energy in the today's ever developing societies investigation on the designing of power plants for production of electricity as an efficient and requiredinstallations seems necessary in development of the societies. Hydroelectric powerplants are important due to using water resources as pure and renewable resources and less environmentalpollutioncompared toother power plants. Hydroelectricpower plants and dams are affected by major factors in designing and construction process and lack of identification and evaluation lead to irrecoverableconsequences in productionand profitability stages. Given the number and characteristics of these factors, the use of scientific methods in management decision making and evaluation is necessary. Among these strategies there is multi-criteria decision making method.This method consists of techniques and analytic hierarchy process as one of the most widely used techniques in the field of multi-criteria decision making method. Key features and criteria were identified in this study related to dams and power plants in Kurdistan Gardalan and results were provided at the end of the study.
Keywords:Decision making, Multi-criteria decision making, Key decision attribute in decision making,Decision making criteria, AHP

INTRODUCTION

Energy security is crucial to the development of modern societies. New research has shown that there is a direct relationship between country's level of development and its energy consumption. The design and construction of dams and hydroelectric plants as a method of producing electricity are strategically important. Hydropower or hydroelectricity is the term that refers to the electrical energy produced by the force of the water flow. Hydroelectricity is produced currently about 715,000 megawatts or 19 percent (in 2003 sixteen percent) of the total electrical energy generated covered inthe world. Hydroelectric power includes 63 percent of the electrical energy generated from renewable sources. There are long-term development programs in Iran based on the design and construction of these power plants (Bozorgzadeh,2009).

Given the number of factors in the designing and construction of dams and power plants it can be referred to technical indicators, economic, social, environmental factors and need to analyze and evaluate all indictors', multi-criteria decision-making processes as the scientific method. The decision to this effect is used. AHP is one of the most famous multi-criteria decision making techniques in this field of research that has already been used. In other words, the complex decision process is divided into manageable sections. And better understanding of the elements is achieved by integration of decision criteria. In this way, the qualitative and quantitative data are scoring through the paired comparisons.

Among different factors effective in designing and constructionprocess of dams and power plants there factors that have more effect so that their accurate evaluation and determinationplay an important andstrategic role in their success and in other cases they can cause irreparable damage to the project that can give a lot of spending plans or lead to stagnation and the loss. The importance of this stage of the studies should be handled carefully before erecting and commissioning of these projects.

In terms of development programs and projects, hydroelectric dams and hydroelectric power has potential in the identification of challenges, constraints and requirements of the development projects as largeindustries. According to limitations andnecessities and importance of energyin progress of the strategic plans in other sectors it is necessary to use proper executive methods and decisions making. In thisregard the aim of this research is to identify of the key factors and criteria in designing of hydroelectric powerplants and their evaluation and grading by using AHP.

MATERIALS AND METHODS

Decision making

Anticipate, evaluate and compare existing solutions and a choice of solutions to achieve optimal decision is decisions making. Decisions making involve small part to the large and play an important role in human life and the results are manifested in all aspects.

Multi-criteria decision

Developments in the today worldand consequently more complex decision environments have led the researchers to focus on multi-criteria decision-making model. This type of decision makingratherthanameasure of optimality, multiple criteria are used together to determine the best option. Satisfaction with the decision making system is achieved.

Criteria decision making model is divided into two multi-objective constructs based on multi-criteria decision making method:

1-Multipurposedecisions making

Thedecision maker could encounter with several objectives concurrently and in this case these issues can be investigated by decisions making with multiple purposes. So thatDecision making purposes is expressed as a multiple objective functions andthese functions will be optimized solution. Mathematical model of multi-objective decision functions is as follows:

$$\{f_1(x), f_2(x),..., f_n(x)\}$$

$$s.t: g_i(x) \begin{bmatrix} \leq \\ \geq \\ = \end{bmatrix} 0 \ ; \ i = 1, 2, 3, ..., m$$

2-Multi attributesdecision making

Thedecision maker encounters with differentproblems and the problems should be evaluated and graded based on the present options and one option should be chosen as the selected one.

Table1. Types ofmulti-criteriadecision-makingmethods

Non-interactiveMethods	Method of solving No preferences criterion(Dominatemethods، Method ofMinimumMaximums، Method of MinimumMaximums)
InteractiveMethods	Method of solvedwithstandard level (method of Satisfyindividual، method of SatisfyComprehensive) Method of solving withqualitativepreferences(Playoffmethod، Method ofdictionary،Method of halfofdictionary،Method of Permutation) Method of (SAW) Simple Additive Weighting Method of Compromise programming Method of(VIKOR)Vlsekriterijumska optimizacija I Kompromisno Resenje- (Phrase Serbian) Method of (TOPSIS)Technique for order preference by Similarity to Ideal Solution Method of (ELECTRE)Elimination choice translating reality Method of(AHP)Analytic hierarchy process Method of(ANP)Analytical Network Process

Decision making criteria

Criteria are considered as benchmark to ensure that the decisions are objective and constructive in order to maximize utility and satisfaction. In other words, the criteria represent the standards and laws that are used to judge the effectiveness of the decisions. Whatever in the criteria the greater part of its surrounding and expression are likely to be increased more accurate results are achieve. (Atai, 2010)

Dams and hydroelectric power plants

Any obstacle in flow of water leads to increase the height of water and saving it and it is called dam.In other hand, dam is a structure constructed in width of livers in order to collect and increase height of water. Hydroelectric power plants are constructed near dams for production of electricity by using water collectedbehind dams and the energy is converted into gravity energy with generator turbines.

Key characteristics and design criteria for dams and hydroelectric power plants

In this research four key characteristics and attributes and criteria are introduced for measuring each attributeaccompanied by interview with the experts of Iran power and water resourcesfirm and library studies.

Selectionof place of dam and power plant

Localization and establishment of industrialunits is one of the key steps since theseaffairsindicate their effect in long term and they are effective in implementation of the projects from economic, political and social,environmental, natural and humanresources.Select a suitable site requires the recognition criteria to evaluate the abilities of different areas to be correct and desirable. Proper site selection criteria that were considered in this study include:

environmentalconsequences
The topography of the area
Access routs
Geological structures

Selection of the type of dam and its body

Sincewater collected behind a dam could apply considerable amount of forces on the dam body so the static and stability of dam is considered in designing and the dams are classified into a gravel embankments or concrete coverage (CFRD) and concrete dams are divided. Criteria considered for evaluating and selecting the appropriate option in the properties are as follows:

Geological conditions
Building Materials
Hydraulic Structures
Cost

Selection of the type of power plant

Hydroelectric dam downstream of the existing environment and security issues are considered in the three-surface level, substrate level and underground. Criteria used in this specification are:

Construction Cost
Limitations of space
Passive Defense

The plant operation coefficient and capacity factor

Balance between demand and supply of electrical energy is one of the main goals of an electric power supply system. Hydroelectric development, the main goal is to design a power plant or a few plants, where the water, with maximum economically feasible to produce hydroelectric power.

The problem of generation capacity and coefficient of performance for the initial stages of research is proposed in order to justify the hydropower potential. The objective of this phase of the study is to ensure economic and estimate the scope and costs of plant construction project. At each site, hydroelectric installed capacity and optimum operating parameters must be such that the profitability index of the project to reach its maximum. The following criteria will be considered for the index function (Shariyatzadeh, 2011):

The amount of energy
Electricity Market
Cost
Sources of water flow

AHP

The data collected from the hierarchical analysis of clinical research in the field of multi-criteria decision making techniques are used.

This method was first proposed in 1980 by Thomas Saati and it is based decision making paired comparisons. The comparison of each of the alternatives evaluated according to the criteria and their relative weights are calculated. The logic of such matrices of AHP is paired comparisons which makes the combined weight of the decision optimal (Mehregan, 2006).

Practical application of the analytic hierarchy process involves four basic steps(Atai, 1389):

First, the hierarchical diagram: In this stage, the decision problem is decomposed into a hierarchy of levels in the graph. The first layer indicates main objectives of the decisions making and the second layer containsprinciple indices and the third level offers decisions making options.

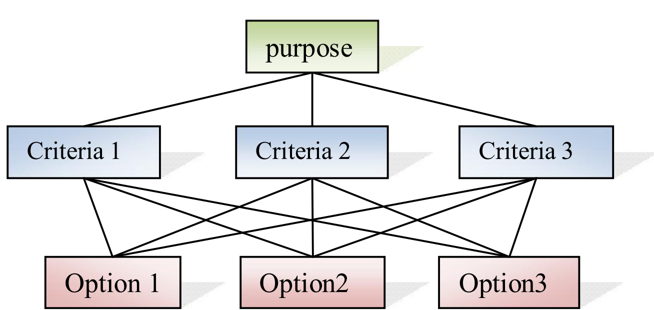


Figure 1. hierarchical diagram

In the second step every level is measured as indices and options relative to related element in higher level as pair. This measurement is done by formation of matrices that their importance is determined numericallyrelative to each other and then the options are selected . In order to calculations and measuring indices weights the scores of distributedquestioners are used that they are proposed as pair comparisonaccording to Table 2.A paired comparison matrix is shown below: (Atai - 1389).

Table2.Bachelorpreferences

Preferences	Numeric value
Fullpriority	9
Verystrongpreference	7
Strongpreference	5
Lowpreference	3
Equally important	1
Preferencesbetween theintervals	2,4,6,8

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

The matrix element aij is the element of favor i relative to j. In the paired comparison matrix of criteria other than the base diameter of the inverse matrix are:

$$a_{ij} = \frac{1}{a_{ji}}$$

Pairedcomparisonmatrix is as n*n where n is number of indices of each level relative to related indicescomparedin its higher level.

For each paired comparison matrix, the diagonal elements are equal and do not need to evaluate the other matrix and the elements should be determined based on paired comparisons. Symmetric relative to the diagonal entries of the matrix are inverse to each other. The number of paired comparisons for each paired comparison matrix is:

$$N_c = \frac{n(n-1)}{2}$$

In general, if the decision of m alternatives and n criteria must be paired comparison matrix n a paired comparison matrix. The number of paired comparisons hierarchy (the whole thing) is:

$$N_h = \frac{n(n-1)}{2} + \left[n \times \frac{m(m-1)}{2} \right]$$

Different methods for calculating the relative weights of the paired comparison matrix are the most important, least-squares, logarithmic least squares method, eigenvector methods and techniques are approximate. Among these methods, the eigenvectors method is more accurate.

In this study, using the arithmetic mean method of calculating the relative weights are approximate and we calculate the relative weights of criteria and alternatives. This is expressed by the following formula and we normalized each column and each row vector of average weight was achieved.

$$\frac{\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}}{\sum_{i=1}^{n} x_{i1} \quad \sum_{i=1}^{n} x_{i2} \quad \sum_{i=1}^{nm} \sum_{j=1} x_{ij}} \Rightarrow \begin{bmatrix} \frac{x_{11}}{\sum_{i=1}^{n} x_{i1}} & \frac{x_{12}}{\sum_{i=1}^{n} x_{i2}} & \cdots & \frac{x_{1m}}{\sum_{i=1}^{n} x_{ij}} \\ \frac{x_{21}}{\sum_{i=1}^{n} x_{i1}} & \frac{x_{22}}{\sum_{i=1}^{n} x_{i2}} & \cdots & \frac{x_{2m}}{\sum_{i=1}^{n} x_{ij}} \\ \cdots & \cdots & \cdots & \cdots \\ \frac{x_{n1}}{\sum_{i=1}^{n} x_{i1}} & \frac{x_{n2}}{\sum_{i=1}^{n} x_{i2}} & \cdots & \frac{x_{nm}}{\sum_{i=1}^{n} x_{ij}} \end{bmatrix} \Rightarrow \begin{bmatrix} \dfrac{\frac{x_{11}}{\sum_{i=1}^{n} x_{i1}} + \frac{x_{12}}{\sum_{i=1}^{n} x_{i2}} + \ldots + \frac{x_{1m}}{\sum_{i=1}^{n} x_{ij}}}{m} \\ \dfrac{\frac{x_{21}}{\sum_{i=1}^{n} x_{i1}} + \frac{x_{22}}{\sum_{i=1}^{n} x_{i2}} + \ldots + \frac{x_{2m}}{\sum_{i=1}^{n} x_{ij}}}{m} \\ \cdots \\ \dfrac{\frac{x_{n1}}{\sum_{i=1}^{n} x_{i1}} + \frac{x_{n2}}{\sum_{i=1}^{n} x_{i2}} + \ldots + \frac{x_{nm}}{\sum_{i=1}^{n} x_{ij}}}{m} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ \cdots \\ a_n \end{bmatrix}$$

The final weight of each item on an analytic hierarchy process, multiplying the weight of each criterion is obtained by the rating option. Total points earned for each option can be obtained from the following equation:

$$A_{AHP_{Score}} = \sum_{j=1}^{n} a_{ij}.w_j = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ \cdots & \cdots & \cdots & \cdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ . \\ w_j \end{bmatrix} \qquad i=1,2,\ldots,m$$

where aij represents the relative importance of alternative i for criterion cj and wj is the importance of weight and measure. It also has the option values and weights of indices are normalized using the following relations.

$$\sum_{i=1}^{m} a_{ij} = 1 \qquad i=1,2,\ldots,m \qquad\qquad \sum_{j=1}^{n} w_j = 1$$

The final weight of each feature by calculating the options, the options is selected.

One of the benefitsof AHP is control of consistency of decisions making. In other hand; the level of consistency can be calculated in AHP and judge acceptability and rejection of the measurements. In case of a inconsistency rate of 1/0 comments should be reviewed in the judgment and it is used to calculate the adjustment process (Atai, 1389)

1. Calculation of sum of the weight vectors: by the paired comparisons matrix we multiply the column vector of relative weights. Vector can be obtained through this new vector that is called a weighted sum.
2. Calculate the consistencyvector: vector elements obtained in the first stage and the weighted sum of the relative weights assigned to the vector. The resulting vector is called vector compatibility.
3. Calculate Maxλ: Maxλ givesconsistency vector elements.
4. Consistency Index: it is obtained fromfollowingformula.

$$CI = \frac{\lambda_{Max} - n}{n-1}$$ n: is the number of options in the

5.-consistencyratio: in this stage adaptation of the index into the random consistency ratio obtains.

$$CR = \frac{CI}{RI}$$

Table 3. randomized Indicators

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.51

So, according to problem characteristics and using AHP at first the main attributes and criteria for designing dams and hydroelectric plants were determined as AHP and then byusingnumericalscales range 1-9 obtained by questionnairescompleted by industrial experts the pair comparisonmetrics were formed and the options and the scales were weighted . Finally, byestimation of consistency of obtainedweights the preferred and optimal options are chosen.

Research Questions

Which characteristics and parameters of dams and power plants are highly rated based on hierarchical analysis?

Is AHP suitable for evaluation of the key features in the design of dams and hydroelectric plants?

RESULTS

Numerical Example

In this example, the site of the dam and the power plant and feature of the study are described.

First,a hierarchical graph is drawn for dam and power plant site.

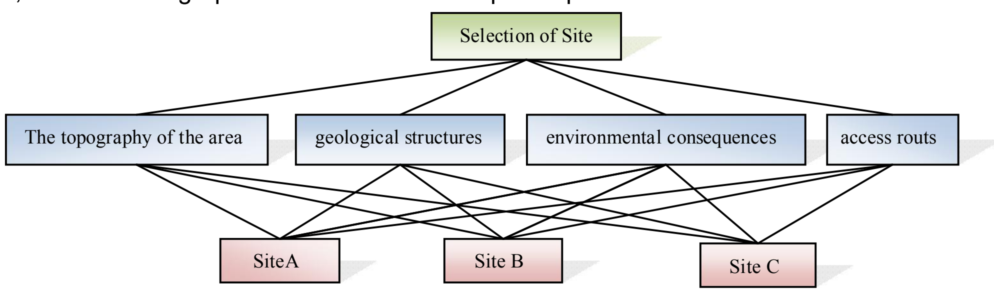


Figure 2. Diagramof hierarchicalselectiondam and powerhouse

Second, the decision matrix is formed and paired comparisons are carried out between alternatives based on the criteria of the site and its paired comparisons of criteria.

Table4: Paired comparisons of dam site selection with criteria geological structure

	Site A	Site B	Site C
Site A	1	1/4	1/2
Site B	4	1	4
Site C	2	1/4	1

Table5: Paired imprisons of dam site selection with criteria topography of the area

	Site A	Site B	Site C
Site A	□	4	3
Site B	1/4	□	2
Site C	1.3	1.2	□

Table6: Paired comparisons of dam site selection with criteria access routes

	Site A	Site B	Site C
Site A	□	1.2	1.3
Site B	2	□	1.2
Site C	3	2	□

Table7: Paired comparisons of dam site selection with criteria environmental consequence

	Site A	Site B	Site C
Site A	□	□	□
Site B	□	□	2
Site C	□	1.2	□

Table8: Paired comparisons criteria dam site selection

	topography of the area	geological structures	environmental consequences	access routs
The topography of the area	□	1.3	2	□
geological structures	3	□	6	5
environmental consequences	1.2	1.6	□	2
access routs	□	1.5	1.2	□

Third step involves the calculation of the relative weights and consistency ratio for each of the weights.

Table9:Calculate the relative weight of dam site selectionwith criteria geological structure

	Site A	Site B	Site C	Inconsistency
weight	0.131	0.661	0.208	0.05

Table10:Calculate the relative weight of dam site selectionwith criteria topography of thearea

	Site A	Site B	Site C	Inconsistency
weight	0.630	0.218	0.151	0.1

Table11:Calculate the relative weight of dam site selectionwith criteria environmental consequence

	Site A	Site B	Site C	Inconsistency
weight	0.327	0.413	0.260	0.05

Table12:Calculate the relative weight of dam site selectionwith criteria access routes

	Site A	Site B	Site C	Inconsistency
weight	0.163	0.297	0.540	0.009

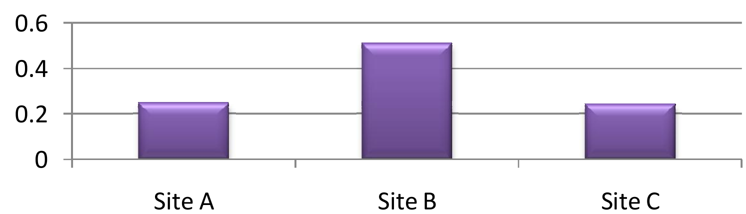
Table13:Calculate the relative weight of dam site selectioncriteria

Table13	topography of the area	geological structures	environmental consequences	access routs	Inconsistency
weight	0.177	0.583	0.128	0.112	0.07

Fourth, relative weights are integrated to calculate the net weight of the dam and powerhouse options for site selection.

Table14: The final weight of the dam and powerhouse site for choosingappropriatesite .

Site A	Site B	Site C
0.248	0.510	0.242



DISCUSSION AND CONCLUSION

Today according to complexity of the decisionmaking and diversity of the effective factors on decisions the use of multi-criteria decision-making methods is considered for solving problems and providing appropriate solutions and results for managers and professionals. (Atai, 2010)

Every project follows particular factors due to its geographical conditions. Evaluation is usually done beefierimplementation and production of the project by feasibilitystudies in order to reduce side effects and empower positiveeffects.Dam and plant projects are importantprojectsbecauseof effect of different strategic factors like political, economic, and social and environmental factors. Thusutilization of appropriate strategy in decision making process seems necessary in etiology of different problems and reduction of problems and increase output.

By using AHP as an efficient method in multipurposedecisionmaking it can be achievedeffective results in evaluation and selection of the optimalcriteria.

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