International Journal of GEOMATE, March, 2019 Vol.16, Issue 55, pp. 184 -194
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.55.87673
Special Issue on Science, Engineering & Environment

REVIEW OF CRITERIA ON MULTI CRITERIA DECISION MAKING (MCDM) CONSTRUCTION OF DAMS

*Imam Santoso[1], Suripin[2], and Suseno Darsono[2]

[1]Civil Engineering Department-Engineering Faculty - Diponegoro University, Indonesia; [2] Civil Engineering Department-Engineering Faculty - Diponegoro University, Indonesia

*Corresponding Author, Received: 27 Juny 2018, Revised: 07 Aug. 2018, Accepted: 01 Oct. 2018

ABSTRACT: Complexity of dam construction leads to special attention when it comes to constructing in terms of determining the priority scale of development if there are several alternative locations related to various criteria. These criteria include: technical (engineering), economic, social, cultural, environmental, legal, institutional and even political criteria. Some experts have pointed out that the selection of dams associated with the site requires significant empirical input from experts and specialists in the form of heuristic rules, expert opinions and conclusions, and applicable rules. This problem can be solved by using the Multi-Criteria Decision-Making (MCDM) approach. MCDM or Multiple-Criteria-Decision-Analysis (MCDA) is expressed as a decision-making method to establish the best alternative of a number of alternatives based on certain criteria. Some of the models included in the popular MCDM used today are: Scoring Model, Analytic Herarchy Process (AHP), Analytic Network Process (ANP), Utility Model, Out Ranking Method, and Technique for Others Reference by Similarity to Ideal Solution (TOPSIS) and others. The application of MCDM in relation to the analysis of priorities for dam construction (best location determination) has also been developed. An appropriate method for determining priority scale of dam construction is needed so that the built construct is based on complexity and multi dimension. This paper will discuss some of the studies that have been done in determining the priority scale of dam construction with the MCDM approach and will provide an overview of the possibility of further research that can be done.

Keywords: ANP, Dam, Priority

1. INTRODUCTION

Dams are man-made barriers, built on natural terrain to control or store water [1-4]. The dam building is also a complex facility that usually includes water impoundment, control structures, reservoirs, spillways, work outlets, power houses, and canals or water channels [2-6]. Dams are also not cheap, because dam costs can be huge, for example, the 3 (three) dams examined by the commission cost about $ 6 billion [5]. So that the dam can be concluded as a complex building with a fairly expensive cost.

Once the complexity of the waterworks is concerned, special attention needs to be given when the contructing will be linked to determining the priority scale of its development if there are several alternative locations. Even because it is complex and multi-dimensional, so many criteria must be used, calculated, and analyzed starting from policy, vision, mission, goals, institutional, engineering and management [6]. Similarly includes the process of dam construction starting from the study, planning, implementation and maintenance operations. These criteria include: technical (engineering), economic, social, cultural, environmental, legal, institutional and even political criteria. Discloses that the selection of dams associated with the site requires significant empirical input from experts and specialists in the form of heuristic rules, expert opinions and conclusions, and applicable rules [7].

In some countries there have been guidelines related to site and type for dam construction [3,8] that are considered to be used as a priority-making reference, such as: [2], has issued guidelines for General Design and Construction Considerations for Earth and Rock-Fill Dams. Currently in Indonesia, the determination of the location and type of dam is based on several regulations such as the General Criteria Design Guidelines for Dam (Directorate General of Water Resources Dam Dam, 2003). The guidelines mention some of the basic criteria for dam construction, including: dam types, surveys and investigations, hydrology, loads, foundation designs, earth fill dams, rock fill dam, spillway, instrumentation, and river diversion work. However, the criterion is dominant only from the engineering side where the location and type of dam is determined. This means that the guidelines can not be used to choose alternatives or the determination of priority scale of dam construction. In West Java with several social, economic, environmental, technical, and benefit criteria, a study related to the determination of priority of dam construction has conducted [9]. But the criteria used in the study is still in the level of criteria not yet to the sub criteria. So it needs research related to determining priority scale of dam construction in Indonesia.

In the process of determining the priority scale of dam construction, it will certainly be closely related to the criteria (factors) associated with dam construction [10]. These criteria can be technical and non-technical. The selection of the best dam types for a particular location requires a thorough consideration of the characteristics of each species, as they relate to the physical features of the site (geology) and adaptation to the intended dam objectives, security, economic and other related limitations [7]. This opinion is also reinforced by [11], that the selection of suitable dam sites is one of the issues related to water resources management, and depends on a set of many qualitative and quantitative criteria/attributes. This is because: (1). Some criteria/attributes are not measurable/qualitative complex; and (2). One criteria has a lot of information (eg geological criteria have complex information). This problem can be solved using the Multi-Criteria Decision-Making (MCDM) approach [4,8-12].

MCDM or Multiple Criteria Decision Analysis (MCDA) is an operational research sub-discipline that explicitly evaluates several conflicting criteria in decision making [14]. MCDM is expressed as a decision-making method to establish the best alternative of a number of alternatives based on certain criteria [15]. The advantage of this method is to take into account both financial and nonfinancial (measurable and immeasurable) impacts [8,9]. Some of the models included in the popular MCDM used today are: Scoring Model, Analytic Herarchy Process (AHP) [10, 11], Analytic Network Process (ANP) [20], Utility Theory/Model [21], Out Ranking Method [22], Technique for Others Reference by Similarity to Ideal Solution (TOPSIS) [23], ELECTRE [24,25], PROMETHEE [25,26], and others [6,16].

The application of MCDM in relation with analysis of priorities for dam construction (determine best location) has also been developed [5,17,18]. A case study in Iran, using AHP to select/define the location of the check dam, and involving five (5) main criteria; erosion quantity, materials availability, catchment characteristics, runoff, and socio-economic factors [31]. This criteria is used to rank priorities of several dams candidates with uniform and binomial distributions. Next [11], modified AHP with fuzzy approach to determine the best dam location with several criteria (dam safety, cost, topography, access to materials, economics, water quality, water volume, river flow regime, sedimentation, social, political). This research has also produced the weight of influence of each criteria for determining dam location. In Korea, [32], applying AHP, ELECTRE III, PROMETHEE II and Compromise Programming as MCDM for the selection of dam sites. The case in Indonesia has been conducted by [33], using AHP to determine the priority of small dam construction (small dam) or ponds. So it can be inferred that MCDM has been able to determine the priority scale of the dam site construction in general.

Based on previous dicussion, the appropriate method for determining priority scale of dam construction is needed so that the built dam is based on the complexity and multi dimension. This paper will discuss some of the studies that have been done in determining the priority scale of dam construction with the MCDM approach and will provide an overview of the possibility of further research that can be done.

2. PROBLEM FORMULATION

1) What are the criteria/attributes used in prioritizing the location or dam type.
2) Which MCDM model has been widely used in determining the location and dam type.

3. PURPOSE OF THIS PAPER

1) Identify/create longlist of factors/criteria affecting site selection and dam type;
2) Determine which MCDM methods are specifically focused on site selection and dam type.

4. ANALYSIS AND RESULT

4.1. Priority Determination of Dams

There are many factors related to determining the priority scale of dam construction if a dam is to be built [22,26,27]. Previous research on the criteria for dam construction has been done in various locations. Examples of such studies are: [36], discusses the criteria dam type related to environmental effects, [31] conducted a study in Iran related to the determination the location of a small dam, [32] in South Korea, and in Indonesia [24,26] conducted a study related to the determination the location of small dams in Semarang regency. [35] has also done the same thing with different criteria in Bortala, China. From several previous studies can be inventoried criteria and sub criteria associated with determining the priority scale of dam construction are:

4.1.1. Technical Factors

Technical factors include;

1) Topography;
    a. Vegetation cover in inundation area
    b. Land slope and abutment stability
    c. Volume of embankment material
    d. Acquired area

e. River condition at the plan location (curve or flat)
f. Shape of the valley
g. The existence of a ravine with steep walls & the difficulty of identifying the soil material on dam site
h. Possible valleys in favor of transporting soil material
i. Changes of valley cross section
j. Abutment tilt change
k. Gradient abutmen valley
l. Width of the valley

2) Geology
   a. Soil type at base foundation
   b. Foundation excavation
3) Geotechnical
4) Hydrology
   a. River debit or PMF
   b. Rain
   c. Effective volume
   d. Sediment storage or annual sediment volume
   e. Catchment area
   f. Surface area reservoir
   g. Water retention time in reservoir
   h. Flood of biomass
   i. Long section of river catchment
   j. River length/ river in dry condition
   k. The amount of downstream creeks
   l. River flow regime
   m. Aggressive water effect on the dam
   n. The difference between headwater & tailwater
   o. The possibility of wave action
   p. Possibility of ice action
   q. Simplicity of river diversion
   r. Annual evaporation rate
   s. Soil infiltration rate
   t. High dam
   u. The size and location of the spillway
   v. The shape or appearance of the dam
   w. The position of the intake structure
   x. Annual water volume passing through the main river cross section
5) Environment
   a. Environmental ecology and water quality
   b. Diversity of fish and endemic species
   c. Critically affected natural habitats

4.1.2. Non Technical Factor

Non-technical factors include:

1) Accessibility
   a. Distance quarry
   b. Distance access to dam
   c. Access to materials and facilities
2) Effectiveness
   a. Length of operation or service period
   b. Water price per m3
   c. Speed of development
   d. Availability of construction materials
   e. Conditions at the stage of development
   f. Climate and time available for development
   g. The knowledge and courage of the engineers
   h. No personnel with certain skills
3) Social
   a. Populations that need to be evacuated or require resettlement
   b. Land or land status
   c. Community response
   d. Infrastructure that must be replaced or moved
   e. Cultural wealth affected
   f. Welfare of society and culture
4) Economics
   a. Cost
      Land acquisition costs
      Construction cost
      Operating and maintenance costs
   b. Benefit
      Area of irrigation area
      Benefits of raw water
      Reservoir or reservoir function
      Economic development or economic condition of the country
      The purpose of water use in the reservoir and the cost-benefit relationship
5) Security
   a. Possibility of reservoir stratification
   b. The possibility flood during the construction period
   c. Danger of war and sabotage
   d. Danger from dam body and reservoir
   e. Possibility of dam collapse
   f. Seismicity or earthquakes
   g. Effect of under lift style of dam
   h. Water shortage for development
6) Politics
   Conservative contracts, standards and decisions for each country

These criteria and sub-criteria will be considered for determining priority scale of dam construction. So it is necessary method to assess the influence factors of each criteria for result.

Criteria is a measure that becomes the basis of assessment or determination of something (Indonesian Dictionary). The criteria are usually the measures, rules, or standards used in decision making. These criteria are then used as a reference in decision making methods to establish the best alternative from a number of alternatives [15].

4.2. Multi Criteria Decision Making (MCDM)

MCDM or Multiple-Criteria-Decision-Analysis (MCDA) is an operational research sub-discipline that explicitly evaluates several conflicting criteria in decision making [16]. In [15], MCDM is expressed as a decision-making method to establish the best alternative of alternatives number based on certain criteria. According to [16], the advantage of this method is to take into account both financial and nonfinancial (measurable and immeasurable) impacts. According to [37], some of the models included in the popular MCDM used today are: Scoring Model, Analytic Heiarchy Process (AHP), Analytic Network Process (ANP), Utility Model, Out Ranking Method, Technique for Others Reference by Similarity to Ideal Solution (TOPSIS), and others.

Related to the problem of determining the priority scale of dam construction with many criteria, because of so many criteria, in the decision-making system of dam construction in Indonesia, it is necessary to study the method that will be used. In fact, often the criteria are not mutually supportive, conflicting and mutually debilitating. MCDM in this case can be used as a tool to solve this problem.

Multi criteria method using AHP is widely used in priority of dam construction [11,25,28,29,31,34]. AHP is one of the methods that can be used in decision-making system. AHP was developed by Thomas L. Saaty in the 70s. This method will describe the complex multi-criteria problem into a hierarchy. The hierarchy is defined as a representation of a complex problem in a multi-level structure where the first level is the goal, followed by the factor level, criteria, sub criteria, and so on to the last level of the alternative [15,16].

The decision-making process is basically choosing the best alternative. Such as structuring issues, determining alternatives, determining possible values for alternative variables, value determers, time preference requirements, and risk specifications. No matter how widening the alternatives can be established or detailed the probable value, the limiting limitation is the basis of comparison in the form of a single criterion.

With a hierarchy, a complex problem can be described into groups that are then organized into a hierarchical form so that the problem will seem more structured and systematic. This AHP method can be used although there is no relationship between several criteria.

The working principle of Analytic Hierarchy Process (AHP) Method is:

1) Identification of causal factors
2) Preparation of hierarchy
3) Priority setting
4) Consistency
5) Priority weights

The advantages of using AHP are as follows:

1) Unity (Unity), AHP can make a broad and unstructured problem into a flexible and easily understood model.
2) Complexity, AHP can solve a problem that belongs complex through a system approach and integration deductively.
3) Interdependence, AHP can be implemented on system elements that are not interconnected and does not require linear relationship.
4) Hierarchy Structure, (AHP) can represent natural thinking that tends to group system elements into different levels where each level contains similar elements.
5) Measurement, AHP provides a measurement scale and method for obtaining the priority value of each criterion element.
6) Consistency, the AHP considers a logical consistency value in the assessment used to determine a priority.
7) Synthesis, AHP leads to an overall estimate in the hierarchy to find out how desired each alternative is.
8) Trade Off, AHP considers the relative priority of each factor contained in the system so that people are able to choose the best alternative based on the intended objectives.
9) Judgment and Consensus, AHP does not require a consensus, but combines the results of a different judgment.

Process Repetition, AHP is able to get people to filter the definition of a problem and develop their assessment and understanding through the process of repetition.

The disadvantages of using AHP are as follows:

1) AHP method has dependence on its main input. The main input in question is a perception or interpretation of an expert so that in this case involves the subjectivity of the expert and the model also becomes meaningless if the expert gives a wrong assessment.
2) This AHP method is only a mathematical method. Without any statistical tests based on historical data of problems that have occurred before, so there is no trust limit and strong support information of the correctness of the model that is formed.

4.3 Criteria in MCDM Developed for Priority Determination and Selection of Dam Construction Sites

Several previous studies that have been conducted related to the criteria and sub criteria on the priority of dam construction are seen in Table 1.

Table 1 Research on MCDM for Prioritization of Dam Sites

Influence Factors (CRITERIA)	**Variable** (SUB-CRITERIA)	[36] **Loc.: -**	[31] **Loc.: Iran**	[7] **Loc.: -**	[29] **Loc.: West Iran**	[32] **Loc.: South Korea**	[30] **Loc.: Saudi Arabia**	[35] **Loc.: Bortala, China**	[13] **Loc.: Semarang**
Topography	Vegetation cover in inundation area		√			√	√	√	√
	Land slope and abutment stability		√			√	√	√	√
	Volume of embankment material								√
	Acquired area								√
	River condition at the plan location (curve or flat)			√					
	Shape of the valley			√					
	The existence of a ravine with steep walls & the difficulty of identifying the soil material on dam site			√					
	Possible valleys in favor of transporting soil material			√					
	Changes of valley cross section			√					
	Abutment tilt change			√					
	Gradient abutmen valley			√					
	Width of the valley			√					
	Vegetation cover in inundation area			√					
Environment	Environmental ecology and water quality	√		√	Environment	√			
	Diversity of fish and endemic species	√							

Influence Factors (CRITERIA)	**Variable** (SUB-CRITERIA)	[36] **Loc.: -**	[31] **Loc.: Iran**	[7] **Loc.: -**	[29] **Loc.: West Iran**	[32] **Loc.: South Korea**	[30] **Loc.: Saudi Arabia**	[35] **Loc.: Bortala, China**	[13] **Loc.: Semarang**
	Critically affected natural habitats	√							
Geology	Soil type at base foundation			√	Geology & Geotechnics	√	√	√	√
	Foundation excavation			√					
Geotechnics				√					
	River debit or PMF			√	√				√
	Rain							√	
	Effective volume				√				√
	Sediment storage or annual sediment volume		√		√				
	Catchment area								√
	Surface area reservoir	√							
	Water retention time in reservoir	√							
	Flood of biomass	√							
Hydrology	Long section of river catchment	√							
	River length/ river in dry condition	√							
	The amount of downstream creeks	√							
	River flow regime				√				
	Aggressive water effect on the dam			√					
	The difference between headwater & tailwater			√					
	The possibility of wave action			√					

Influence Factors (CRITERIA)	**Variable** (SUB-CRITERIA)	[36] **Loc.: -**	[31] **Loc.: Iran**	[7] **Loc.: -**	[29] **Loc.: West Iran**	[32] **Loc.: South Korea**	[30] **Loc.: Saudi Arabia**	[35] **Loc.: Bortala, China**	[13] **Loc.: Semarang**
	Possibility of ice action			√					
	Simplicity of river diversion			√					
	Annual evaporation rate				√				
	Soil infiltration rate						√		
	High dam			√					
	The size and location of the spillway			√					
	The shape or appearance of the dam			√					
	The position of the intake structure			√					
	Annual water volume passing through the main river cross section				√				
Effectiveness	Length of operation or service period	√							√
	Water price per m^3								√
	Speed of development			√					
	Availability of construction materials			√					
	Conditions at the stage of development			√					
	Climate and time available for development			√					
	The knowledge and courage of the engineers			√					
	No personnel with certain skills			√					

Influence Factors (CRITERIA)	**Variable** (SUB-CRITERIA)	[36] **Loc.: -**	[31] **Loc.: Iran**	[7] **Loc.: -**	[29] **Loc.: West Iran**	[32] **Loc.: South Korea**	[30] **Loc.: Saudi Arabia**	[35] **Loc.: Bortala, China**	[13] **Loc.: Semarang**
Accessibility	Distance quarry	√							√
	Distance access to dam	√	√						√
	Access to materials and facilities			√					
Social	Populations that need to be evacuated or require resettlement	√							√
	Land or land status				Social Factor				√
	Community response		√	√					√
	Infrastructure that must be replaced or moved								√
Cost	Land acquisition costs								√
	Construction cost			Cost Factor	Cost Factor				√
	Operating and maintenance costs								√
Benefit	Area of irrigation area								√
	Benefits of raw water								√
	Reservoir or reservoir function		√						
	Economic development or economic condition of the country			√					
	The purpose of water use in the reservoir and the cost-benefit relationship	√							
	Area of irrigation area			√	√				
	Benefits of raw water			√					
Safety				√					

Influence Factors (CRITERIA)	**Variable** (SUB-CRITERIA)	[36] **Loc.: -**	[31] **Loc.: Iran**	[7] **Loc.: -**	[29] **Loc.: West Iran**	[32] **Loc.: South Korea**	[30] **Loc.: Saudi Arabia**	[35] **Loc.: Bortala, China**	[13] **Loc.: Semarang**
Security	Possibility of reservoir stratification	√							
	The possibility flood during the construction period			√					
	Danger of war and sabotage			√					
	Danger from dam body and reservoir				√				
	Possibility of dam collapse				√				
	Seismicity or earthquakes			√					
	Effect of under lift style of dam			√					
	Water shortage for development			√					
Politics					√				
	Conservative contracts, standards and decisions for each country			√					

5. CONCLUSIONS AND RECOMMENDATIONS FOR NEXT RESEARCH

Several conclusions that can be taken from the discussion based on the description before and the literature search as has been stated, it can be derived the conclusion that the need for a model of decision making in determining the location and type of dam in Indonesia where the application of the model can be used and applied in evaluating dam that already built or for planning new dams.

Some implications related to the utilization of research results must pay attention to several things, as follows:

1) To determine the priority sequence of dam construction or choose the most ideal dam to be built.
2) As consideration in determining dam construction in terms of technical and non-technical criteria.

5. REFERENCES

[1] Schurer J., Wilkinson E., Norfleet J., Sciver J.V., Huntington C., Lee C., Rogers A., Dam Safety Manual, 3th ed. Colorado: Members of The Colorado Division Of Water Resources; 2002.

[2] US Army Corps of Engineers., General design and construction considerations for earth and rock-fill dams, 2004;(July). http://www.usace.army.mil/usace-docs/eng-manuals/em1110-2-2300/entire.pdf.

[3] U.S. Department of Homeland Security., Dams Sector Security Awareness Handbook, 2007.

[4] Affandi D., Kriteria Material Konstruksi Untuk Bendungan Urugan (Studi Kasus Bendungan Sindangheula) Embankment Material Criteria For Dam Construction (Case Study : Sindangheula Dam), 2014:165-180,.

[5] World Commission on Dams., Final WCD Forum Report, Responses, Discussions, and Outcomes, Cape Town; 2001.

[6] World Commission on Dams., Dams and Development:A New Framework for Decision-Making, London; 2000. doi:10.1007/978-0-387-09421-2

[7] Emiroglu M.E., Influences on Selection of the Type of Dam, Int J Sci Technol, 2008;3(2):173-189,.

[8] United States Bereau of Reclamation., Design of Small Dams - A Water Resources Technical Publication, 3th ed. Washington, DC: U.S. Government Printing Office; 1987. https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/SmallDams.pdf.

[9] Ernawati., Penentuan Skala Prioritas Pembangunan Waduk di Jawa Barat, J Sosioteknologi, 2012;11(April).

[10] Stephens T., Manual on Small Earth Dams, A Guide to Siting, Design and Construction, Rome: Food and Agriculture Organization Of The United Nations; 2010.

[11] Minatour Y., Khazaie J., Ataei M., Javadi A.A., An integrated decision support system for dam site selection, Sci Iran, 2015;22:319-330,.

[12] World Commission on Dams (WCD)., Dam-building decisions, Environ Heal Perspect, 2001;109(2):81-83,.

[13] Anjasmoro B., Suharyanto., Sangkawati S., Priority Analysis of Small Dams Construction using Cluster Analysis, AHP and Weighted Average Method Case Study: Small Dams in Semarang District, Procedia Eng, 2017;171:1514-1525,. doi:10.1016/j.proeng.2017.01.477

[14] Toloie-eshlaghy A., MCDM Methodologies and Applications : A Literature Review from 1999 to 2009, Res J Internatıonal Studıes, 2011;21(21):86-137,.

[15] Kusumadewi S., Hartati S., Harjoko A., Fuzzy Multi Attribute Decision Making (Fuzzy MADM), Yogyakarta: Graha Ilmu; 2006.

[16] Majumder M., Multi Criteria Decision Making, In: Impact of Urbanization on Water Shortage in Face of Climatic Aberrations. Istanbul, Turkey: Springer; 2015:35. doi:10.1007/978-0-387-76813-7.

[17] Velasquez M., Hester P.T., An Analysis of Multi-Criteria Decision Making Methods, Int J Oper Res, 2013;10(2):56-66,. doi:10.1007/978-3-319-12586-2.

[18] Saaty T.L., The Analytic Hierarchy Process, New York: McGra w-Hill; 1980.

[19] Saaty T.L., Decision making with the analytic hierarchy process, Int J Serv Sci, 2008;1(1):83,. doi:10.1504/IJSSCI.2008.017590.

[20] Saaty T.L., Theory and Applications of the Analytic Network Process, Pittsburgh: PA: RWS Publications; 2005.

[21] Jansen S.J.T., The Measurement and Analysis of Housing Preference and Choice, Delft, The Netherlands: OTB Research Institute for the Built Environment, Delft University of Technology; 2011.

[22] Roy B., The outranking approach and the foundations of ELECTRE methods, Theory Decis, 1991;31:49-73.

[23] Hwang C.L., Yoon K., Multiple Attribute Decision Making: Methods and Applications, New York: Springer-Verlag; 1981.

[24] Figueira J., Mousseau V., Roy B., ELECTRE METHODS, In: Multiple Criteria Decision Analysis: State of the Art Surveys. ; 2005:1-35. doi:Doi 10.1007/0-387-23081-5_4.

[25] Marzouk M.M., ELECTRE III model for value engineering applications, Autom Constr, 2011;20(5):596-600,. doi:10.1016/j.autcon.2010.11.026

[26] Figueira J., Greco S., eds., Multiple Criteria Decision Analysis: State of the Art Surveys, Springer; 2004.
[27] Abedi M., Ali Torabi S., Norouzi G.H., Hamzeh M., Elyasi G.R., PROMETHEE II: A knowledge-driven method for copper exploration, Comput Geosci, 2012;46:255-263,. doi:10.1016/j.cageo.2011.12.012.
[28] Mardani A., Jusoh A., Nor K.M.D., Khalifah Z., Zakwan N., Valipour A., Multiple criteria decision-making techniques and their applications - A review of the literature from 2000 to 2014, Econ Res Istraz, 2015;28(1):516-571,. doi:10.1080/1331677X.2015.1075139.
[29] Minatour Y., Jahangir K., Mohmmad A., Yasser M., Jahangir K., Mohmmad A., Earth dam site selection using the analytic hierarchy process (AHP): a case study in the west of Iran, Arab J Geosci, 2013:3417-3426,. doi:10.1007/s12517-012-0602-x.
[30] Abushandi E., Alatawi S., Dam Site Selection Using Remote Sensing Techniques and Geographical Information System to Control Flood Events in Tabuk City, Hydrol Curr Res, 2015;6(1):1-13,. doi:10.4172/2157-7587.1000189.
[31] Emamgholi M., Shahedi K., Solimani K., Khaledian V., Suitable Site Selection for Gabion Check Dams Construction Using Analytical Hierarchy Process and Decision Making Methods, 2007;2(4):170-179.
[32] Park D., Kim Y., Um M.-J., Choi S.-U., Robust Priority for Strategic Environmental Assessment with Incomplete Information Using Multi-Criteria Decision Making Analysis, Sustainability, 2015;7(8):10233-10249,. doi:10.3390/su70810233.
[33] Anjasmoro B., Suharyanto., Sangkawati S., Analisis Prioritas Pembangunan Embung Metode Cluster Analysis , AHP dan Weighted Average (Studi Kasus: Embung di Kabupaten Semarang), J MKTS, 2015;21(2):101-112.
[34] Becue J.-P., Degoutte G., Lautrin D., Choice of site and type of dam, Small Dams, 2002:17-22.
[35] Dai X., Dam site selection using an integrated method of AHP and GIS for decision making support in Dam site selection using an integrated method of AHP and GIS for decision making support in Bortala , Northwest China By, 2016.
[36] Ledec G., Quintero J.D., Quentero J.D., Good Dams and Bad Dams: Environmental Criteria for Site Selection of Hydroelectric Projects, Vol 16.; 2003. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Good+Dams+and+Bad+Dams+:+Environmental+Criteria+for+Site+Selection+of+Hydroelectric+Projects#0.
[37] Kornyshova E., Salinesi C., MCDM techniques selection approaches: State of the art, Proc 2007 IEEE Symp Comput Intell Multicriteria Decis Making, MCDM 2007, 2007;(Mcdm):22-29,. doi:10.1109/MCDM.2007.369412.
[38] Njiru F.M., Hydrological information for Dam site selection by Integrating Geographic Information System (GIS) and Analytical Hierarchical Process (AHP), 2017.
[39] Saaty T.L., How to make a decision: The Analytic Hierarchy Process, Eur J Oper Res, 1990;48:9-26,. doi:10.1016/0377-2217(90)90057-I
[40] Food and Agriculture Organization of United Nation., Dam design and operation to optimize fish production in impounded river basins, http://www.fao.org/docrep/005/ac675e/ac675e04.htm. Published 2013.
[41] Moum A.R., Frink D.L., Pope E.J., North Dakota Dam Design Handbook, North Dakota; 1985.