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REVIEW

A Comprehensive Review for the Dams Site Selection Based on Multi-criteria: Assessment and Evaluation

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ABSTRACT

The watershed dams water harvesting establishment is a complex decision-making process due to the existence of several critical factors on which the project is based adopted. Such complexity renders consideration for the priority scale of development, especially when the project considers several possible sites against a plethora of criteria. These criteria may be of a technical, economic, social, cultural, environmental, legal, and political nature, thereby increasing the complexity of the framework under which the decision has to be made. Appropriate solutions for the challenge have to consider Multi-Criteria Decision-Making (MCDM) approaches. MCDM is defined as an organized approach to decision-making designed to help in site selection from amongst alternative feasible sites based on a range of criteria. Most of the prominent MCDM methods used over the literature are including Analytic Hierarchy Process (AHP), Weighted Linear Combination (WLC), Fuzzy logic (FL), Boolean Methods, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The MCDM methods represent a different strategy of integration and analysis of multi-dimensional criteria that influence the choice of the dam site. The advantages of the MCDM methods are not only help to undertake a detailed study of priorities for the construction of the dam; however, they devise a methodological approach to the selection of the most appropriate location of dams for their construction. The present survey exhibited and evaluated all the conducted researches to rank the dam construction projects using the MCDM methods. This review provides an comprehensive assessment and evaluation for the literature and recognizes the opportunities for the improvement of the MCDM methods effectiveness under complex dam site selection problems. The survey is expected to contribute toward refining strategic decision-making processes required for sustainable infrastructure development.

Keywords: Dam site selection, Watershed sustainability, Water resources management, Multi-criteria decision-making, Review

1. Introduction

1.1. Background of the study

Dams are structures made across flowing bodies of water for various reasons, ranging from water control to irrigation and power development; the latter requires great complexity, and such facilities consist of spillways, reservoirs, and powerhouses. The dams themselves are inherently very costly and complex to put in place; they demand intensive study and analysis due to their huge economic, environmental, and social impacts. For example, the costs of three dams studied by a commission came to approximately $6 billion; hence, the importance of proper criteria in choosing the sites, the types, and the other criteria that are technical, economic, social, cultural,

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and legal in nature [1, 2]. The site selection process has, at present, developed into a mature alternative site and type evaluation, which requires heavy inputs from experts in several interdisciplinary fields. The policy, vision, institution management, and engineering are other dimensions that need to be detailed in their considerations. In the case of Indonesia, most of the guidelines for the design and construction of the dam are focused on the engineering criteria; however, comprehensive studies of a region such as West Java suggest the necessity of broader criteria considering the social, economic, and environmental factors [1, 2].

The Multi-Criteria Decision Making (MCDM) comes out as a pivotal technique in this situation, aiding in the integration of quantifiable and qualitative factors while arriving at the most appropriate locations for constructing a dam [3]. Thousands of studies all over the world have successfully used the MCDM methods of the AHP and other methods in the prioritization of dam sites based on the evaluation of diverse criteria, from erosion and material availability to socio-economic impacts. This underlines the fact that the construction of a dam is not just the process of construction of a piece of infrastructure; rather, it becomes the realization of the water necessity, a basic human need and ecological property, which requires sustainable and scientific decision-making in hydraulic projects in order to control the probable environmental damage and make the impacts of dams beneficial to water resource and clean energy development [3, 4].

It considered the complexities and the diversified criteria involved in the assessment, which have made Multi-Criteria Decision Making (MCDM) a popular approach in the area of dam construction. A MCDM approach offers a well-structured framework for analyzing a series of conflicting criteria together, hence enables much improved objectivity and transparency in the process of making decisions. This approach assumes a special role where the decisions are to be made among the alternatives, each possessing sets of advantages and trade-offs [4, 5].

According to the literature, there has been an application of the various techniques of Multi-Criteria Decision Making into the selection of the dam site [7], considering each advantage and operating at a different stage of the decision-making process [8]. Analytic Hierarchy Process, (AHP) is a multi-criteria decision-making method based on breaking a complex decision problem into a hierarchy of more manageable sub-problems, each of which can be analyzed independently before aggregating the results to provide a final decision [9]. Moreover, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is utilized for determining solutions that exist out of a finite set of alternatives in a decision-making problem, according to the smallest possible deviation from the ideal solution, which is easy to compute and has minimal computational effort [10].

Other techniques such as WLC, Fuzzy Logic, and Boolean Methods offer much more flexibility and robustness in handling qualitative data and in the integration of stakeholder preferences in the decision-making process [11]. These methods are applied effectively in dam site selection, particularly when environmental and social issues are prevailing and decision choices are subjective and uncertain.

This paper critically reviews some of the previous studies that applied Multi-Criteria Decision Making methods to prioritize dam construction projects, elaborating on strength and weaknesses of methodologies in details. Therefore, the paper will discuss the scope of the more research being accomplished, which could be one step forward in increasing the effectiveness of the MCDM methods in dealing with complexities in dam site selection.

1.2. Review significance

It is one important reason that MCDM is utilized in this kind of dam site selection. First, it presents its rational and systematic transparency in nature, which is critically desired in any form of decision-making toward public infrastructure projects. Second, Multi-Criteria Decision Making balances the input of quantitative data and qualitative judgment in such a way that assures that every factor, ranging from community preference to environmental-impact factors, is fully taken into account. This is very significant in dam construction projects, as the impacts extend far beyond just physical and economic effects to include the ecological system and local community [12]. A key additional role of Multi-Criteria Decision Making is the realization of sustainable development goals through the consideration of environmental and social factors on par with the technical and economic criteria. A holistic approach is called for to this end, so that any possible negative impact in the long run can be balanced out by achieving long-term ecological equilibrium and long-lasting social welfare [11].

1.3. Review objectives

This review has been conducted with the following in mind:

- Evaluation of alternatives available for selection of dam sites,

- Understanding the handling of available methods to integrate the diverse criteria,
- Enabling synthesis of available case studies and literature for recommendation of improvements in MCDM applications.

2. Literature review

Increased human population and the growing urbanization have been accompanied by diverse and heavy uses of water, which consequently created several socio-economic problems, and the management of water resources became the major issue [13]. Water is extensively utilized across several sectors including agriculture for crop cultivation, construction for building infrastructure, domestic purposes such as cleaning and bathing, and energy generation, particularly electricity. Agriculture satisfies societal needs for food through crop production, construction addresses housing demands, domestic use encompasses everyday water activities, and energy generation supports electricity requirements. A critical concern projected for the future is the scarcity of water resources, particularly affecting arid and semi-arid regions. Numerous strategies have been proposed to mitigate this looming crisis, including the development of water storage facilities such as dams. However, choosing locations for such infrastructure presents a significant challenge for decision-makers [37]. Numerous criteria and sub-criteria must be evaluated when identifying suitable locations for dam construction. Consequently, the task of selecting dam sites represents a Multi-Criteria Decision Making (MCDM) challenge, a topic that has been extensively explored by various scholars. The contributions of these researchers [38, 48] are particularly significant in this field.

3. Multi-criteria decision making

MCDM (Multiple Criteria Decision Making) or MCDA (Multiple-Criteria-Decision-Analysis) is a specialized branch of operations research that tackles the challenge of evaluating and making decisions among alternatives based on multiple, often conflicting criteria. It enhances decision-making by accounting for measurable and immeasurable, financial and nonfinancial impacts, using a variety of models including the Elimination and Choice Translating Reality (ELECTRE), Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Decision Making Trial and Evaluation Laboratory (DEMATEL), Out Ranking Method, Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) are presented in Table 1. This makes the approach particularly valuable for dam-siting decisions, which involve criteria across hydrology, topography, geology, environment, and socioeconomics.

Applications have utilized Multi-Criteria Decision Making for improved decision-making in dam construction through the incorporation of GIS for geo-analytical processing and the application of techniques such as AHP and TOPSIS, which can effectively deal with different criteria. For example, AHP has been used for the analysis of dam site suitability against government data with spatial distribution results that vary, whereas TOPSIS, which is commonly applied in combination with fuzzy logic, offers optimal solutions by weighting social, economic, and environmental factors. These methodologies have been crucial in tackling water resource management problems; they are proving to have widespread applications from China to Nigeria, emphasizing the need for a structured, hierarchical approach within systems of decision-making, such as in the context of planning the construction of dams in Indonesia. For instance, through its hierarchical structuring using AHP, which involves the division of complex multi-criteria problems at large into manageable, realistic levels, from goals to alternatives, MCDM ensures a systematic and structured process of decision making that takes into account the range of criteria involved in ensuring sustainable and efficient construction of dams [2, 4, 14].

4. Multi-criteria decision-making dam site selection factors

The site selection of a dam is a complex decision-making process, in which numerous factors interconnected with one another are taken into consideration in the determination of the feasibility and sustainability of the project. These can be broadly categorized as presented in Table 2 into topographical, hydrological, and geological aspects besides environmental and socio-economic considerations, each having a huge influence on the design, construction, and operational behavior of a dam.

4.1. Topographical factors

Elevation and slope are key indicators of topographic features. Typically, moderate elevation areas are preferred for dam construction, while regions at lower and higher elevations are less suitable [17, 18]. However, opinions vary on whether steep or

Table 1. Main methods of multi-criteria decision-making.

Name	Full name	Reference
ELECTRE	Elimination and Choice Translating Reality	[15]
AHP	Analytical hierarchy process	[12]
DEMATEL	Decision Making Trial and Evaluation Laboratory	[16]
TOPSIS	Technique for Order Preference by Similarity to an Ideal Solution	[17]
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluations	[18]
ANP	Analytic Network Process	[19]
VIKOR	Vlsekriterijumska Optimizacija I Kompromisno Resenje	[20]

Table 2. Predominant categories and factors of multi-criteria decision-making considered.

Category	Factor
Topography	Land Slope
Environmental	LULC (Land Use and Land Cover)
	Soil Type
Hydrology	Precipitation/Rainfall
	Curve Number
	Stream Order
	Runoff
	Drainage Density
Infrastructure	Distance from Road
Demographics	Distance from Village
Social	Community Response
Geography	Elevation
Geology	Geological conditions
Seismic Activity	Distance from Faults

moderate slopes are more appropriate for dam construction. Some studies indicated that flat terrain is better for dam construction than steep slopes due to the increased risk of landslides and foundation pressure that accompanies steeper slopes [23–25]. Another investigation found that water velocity correlates with slope, recommending a slope of less than 5% for soil and water conservation in reservoirs [26]. However, another scholars suggested that the slope under 15 degrees is ideal and groundwater dams are also typically built on gentle slopes in wide valleys [27].

On the other hand, Some researchers [28] suggested that steep canyons can be excellent dam sites, as they allow for shorter dam axes and greater capacity with less construction earthwork, this perspective is also supported by other studies [29]. Other findings emphasizes the importance of river valley shape, advocating for dam construction at narrow points where the upper river valley widens, typically where slopes are steeper [25]. Additionally research connects valley morphology with dam types, suggesting that earthfill dams are suited to wide valleys, gravity dams to narrow ones, and arch dams to even narrower sites [30].

Slope suitability also depends on the dam's purpose. For rainwater harvesting, the Food and Agriculture Organization (FAO) recommends slopes no greater than 5% [31]. In check dam construction, slope affects reservoir capacity and sedimentation; greater slopes lead to increased sedimentation.

4.2. Hydrological factors

Hydrological parameters define the quantity of a catchment area. Rainfall, runoff, catchment size, river network levels, river network density, and river width are the main ones in hydrology. Rainfall, runoff, river network classification, and river network density have been used in over 20% of future studies. Runoff is mainly from the rainfall, which maintains the proper functioning of the dam if there are no serious weather patterns, such as landslides and floods [32]. The expected volume of runoff can be calculated using the Curve Number (CN) process hydrologic model [33] or be roughly calculated by using the Hydrologic Analysis tool in ArcGIS [34].

The Curve Number is a major variable in establishing the volume of runoff. It's value is a function of the soil type, land use, land cover, and hydrogeological settings. In the assessment of sites for a dam, the catchment area should be big enough to allow storage in the reservoir on a continuous basis and should not be too large, which could result in water storage, thus needing construction of expensive spillways.

The difference of the volumes of runoff among different river network classes is one of the important sources of runoff for the dams, namely, the upstream tributary, and the downstream mainstem. In the meantime, river network density characterizes the water resources in a region; the higher it is, the greater the capacity to divert the water in floods. Also, the river network density is positively associated with the flood volume [35]. Rank of a river network is an indirect index to the runoff volume and in general, higher-ranked rivers usually contain more runoff.

4.3. Geological factors

The geological conditions of a site in the construction of a dam determine the safety and stability of such a project. The geological site condition is also an influencing factor on the type of dam and materials used in its construction [36]. The site should have impermeable geology and an unyielding foundation to prevent leakage. For example, in southwestern China—where landscapes are characterized by karst—the geology will determine if the water will "leak away" after the dam is built. Other geological indicators to be considered are lithology, tectonic zones, distance to faults, and distance to lineaments [37].

Lithology accounts for the majority of the geological factor at 68%, from which faults and tectonic lines are also accounted for [25]. Indeed, the very varied ground rock units are of different stabilities and resistance to pressure from geological epochs [21]. In karst regions, typically found in areas with carbonate rocks, the construction of the underground dams was commonly based on the carbonate rocks, due to which the underground water flow had silted and started to flood some of the lowlands in the upstream regions [38]. Therefore, in the construction of the underground dam in the karst regions, the water holding capacity should be considered, together with the degree of the development of the underground cave system.

Faults are a major contributing factor to landslides [1], hence sites further away from fault lines should be selected to reduce this risk. Tectonic zones and lineaments that are unstable also represent a potential threat, so a site's proximity to these two factors should be considered. Many of the studies I looked into consider one or two of these major geological factors in examining a site, but Othman considered four: tectonic zones, lithology, distance to lineaments, and distance to faults [21]. Some of the tectonic zones, for example, the Imbricated Zone and the High Folded Zone, are generally avoided for their instability. Hence, faults and lineaments mark zones of weakness and are often avoided, with a buffer zone being applied to them.

4.4. Environmental factors

The term "environment" covers a wide range of factors. The area on which we primarily concentrated, however, is factors such as soil characteristics, which considered soil type and erosion, land use, proximity to water bodies, and ground water sources. This list is by no means exhaustive; on the other hand, these are mostly factors frequently discussed in literature. Out of these, land use and soil type are the most common study variables, with usage rate of 88% and 52%, respectively.

Soil types can also be classified through their texture, which determines the rate of soil infiltration and, in turn, volume of runoff. Fine-grained foundations, clays, and clay mixtures of sufficient water resistance provide soil stability [36]. Soil erosion is mostly triggered by high population activity, increased construction, and deforestation. Accelerated erosion in a catchment area results in sedimentation in the storage, which lowers the suitability of soil erosion areas for dam sites designed for the water cycle [39].

4.5. Water quality index

The water quality criteria are very crucial in the selection of the groundwater dam sites because it will determine the quality of the water and its safety for its users to be used as a source of drinking water and other uses. On the other hand, such criteria would be applied in placing surface dams to be used for irrigation and water supply.

Indicators proposed by a research for the estimation of salinity and sodium content in water bodies to ensure the right water quality for performing agricultural irrigation [17]. Indicators including Total Dissolved Solids (TDS), Sodium Saturation Percentage (SSP), pH, and Electrical Conductivity (EC) play a very significant role in the evaluation of soils' suitability for cultivation and rates of infiltration of water and plant growth [26]. TDS was used in a study to estimate the quality of water in a region of the Arabian Gulf where the salinity is very high, posing a very major challenge for management and control [26].

4.6. Socio-economic factors

Different social contexts translate into varying socioeconomic criteria for dam site selection. For example, being close to roads and settlements can reduce transportation costs, accounting for 32% of usage. The distance to infrastructure, such as roads, cities, and villages, is a key metric for estimating construction costs. Choosing a site requires balancing proximity to urban areas with closeness to rural ones, allowing access to both labor and a safety buffer. It also helps reduce risk to such great accidents as dam failures by keeping the dams at a distance from cities [40].

Recent study took into consideration the distances of cities, rural areas, and roads to study the economic location cost of the dam [21]. Investigations considered the social aspects such as resident welfare, culture, and community contribution, and he had been doing field studies to understand the aspects in a better manner [41]. Results of such studies show that the construction of dams affects the communities in the vicinity, and without the involvement and contribution of the locals, the dams cannot have a positive result.

Table 3 below gives a review in detail of the criteria for evaluation and the MCDM in use within dam site selections. It includes the actual considerations, such as land slope, soil type, and community response, and the actual methodologies, like AHP, WLC, and Boolean Methods. All these paints the complex and many-faceted approach required when dam site selection is approached with the intent of accounting for holistic decision-making. It gives a general representation of the in-depth applications of criteria and MCDM methods using qualitative and quantitative data in a number of studies. This typifies the necessity for a challenging, many-faceted approach to ensure the sustainability and appropriateness of dam construction projects.

5. Literature assessment and evaluation

Dams are very important to any country with the need to manage water resources, hydroelectric power generation, and activities used in controlling floods. However, the choice of an appropriate dam site is a difficult, multi-criteria decision-making process involving environmental, technical, and socio-economic criteria. In recent years, MCDM techniques have been used increasingly to work through the complexity in a methodical fashion during the course of analysis of conflicting criteria. In this regard, this analysis (as shown in Fig. 1) would be keen on details regarding the various criteria for site selection for a dam. This discussion should outline any patterns, trends, and considerations that would enlighten the final decision.

5.1. Topographical and geotechnical criteria

Criteria such as land slope and soil type are often analyzed as the most important ones, which reflects their fundamental importance in the creation of dams. Such considerations are very important in land slope mainly because they influence both the hydrologic actions of a dam and their concerns with safety. It affects the free movement of water as well as the pattern of sedimentation, which forms the main criteria in determining the operational efficiency and life of a dam. Equally important is the soil type, for foundational stability and permeability determine structural health and seepage. These have been evaluated, with particular weight placed on the methodologies like AHP or the WLC in showing their effectiveness of integrating quantitative data with expert insights. Such integration will ensure that decisions are made based on balanced and all-round analyses that consider scientific data with practical experience and, therefore, the safety and efficiency of dam structure.

5.2. Hydrological criteria

Run-off and precipitation/rainfall are key hydrological criteria in determining dam sites, which are central elements in approaches to water resources and flood risk management, respectively. They determine total water availability in terms of the reservoir capacity and the capacity of the dam to regulate the hydrological extremes. The techniques TOPSIS and Fuzzy Logic show, however, that the former are a strategic choice of methods due to their proficiency in managing the built-in variance and unexpectedness of hydrological data. This is, in fact, the reason these methods are taken as useful, first to accommodate not only the more-or-less normal seasonal changes but also far wider and unusually erratic changes that climate change introduces in hydrological flows. These, in turn, make the strategies of dam planning and management adaptive to unpredictable environmental changes, making water infrastructure more resilient and, therefore, sustainable. Their advanced analytics should hence be part and parcel of the assessments to allow for comprehensive conclusions guiding site selection and management practices toward sustainability.

5.3. Environmental and socio-economic factors

Combining the LULC data with community feedback in the dam siting process reflects an all-round approach that takes care of the environment while considering the well-being of the community. The LULC data are important for the evaluation of potential ecological disturbances or landscape alterations that the dam construction would cause. This analysis forms the base to development of strategies for the protection of biodiversity and the maintenance of the ecological balance that would ensure environmental sustainability in the dam projects. Equally important is the understanding of the community's perception with respect to these projects. The very importance of feedback acts as a key barometer in a socio-economic scenario. It is a mimicry of genuine concerns and probability of receptivity toward proposed dams. Grasping these community sentiments is not merely important for gaining support but for making the project successful and relevant through time. More often than not, participation of the community in the process leads to dam designs that perform better with respect to the needs and expectations of the

Table 3. Detailed analysis of evaluation factors and methods of multi-criteria decision-making considered for dam site selection.

	Criteria used														
Reference	Land slope	LULC	Soil type	Distance from road	Drainage density	Precipitation/ rainfall	Runoff	Distance from village	Community response	Elevation	Stream order	Geology	Distance from faults	Curve number	Methods applied
[42]		√	√						√		√		√		Heuristics and empirical knowledge from experts
[43]	√	√	√						√		√		√		AHP and Weighted Average
[44]			√						√		√				AHP
[1]									√				√		AHP
[45]	√	√	√	√	√		√				√				WLC
[46]	√				√						√				AHP
[47]	√	√	√	√			√	√			√		√		WLC and Boolean Methods
[48]	√	√	√	√			√	√							AHP, Fuzzy-AHP, (ROM), and (VI)
[49]	√	√	√	√			√				√		√		WLC and Boolean Methods
[50]	√	√	√				√								WLC
[21]	√	√	√	√		√		√		√			√	√	Fuzzy-(AHP) Weighted Sum Method (WSM)
[51]	√	√	√	√	√		√	√							AHP
[25]	√	√										√			AHP and TOPSIS
[26]	√				√	√				√		√	√	√	AHP
[52]	√	√	√				√								Fuzzy and AHP
[22]	√		√	√		√		√		√		√	√		AHP, Fuzzy logic
[53]	√	√								√	√	√			AHP
[54]	√	√	√			√									AHP
[55]	√	√	√	√	√	√									MCA (WLM) combined with GIS
[27]	√	√													AHP and FIM
[35]	√				√						√				AHP
[56]	√	√	√		√		√								AHP
[57]	√	√	√	√	√	√		√		√			√		AHP
[58]	√	√	√		√	√				√		√			GIS, AHP
[59]	√	√	√	√		√		√						√	GIS combined with AHP
[60]		√			√			√				√			Weighted Overlay
[61]	√			√		√	√	√		√					Geospatially based fuzzy logic and AHP
[62]		√				√	√				√				AHP
[63]	√		√					√					√		MCE-GIS
[14]		√							√		√				Fuzzy - AHP
[4]	√						√								Spatial network analysis using RS and GIS
[64]	√											√			AHP
[65]	√	√	√	√								√			Spatial suitability analysis with AHP
[22]	√	√	√			√	√						√		AHP-Fuzzy
[66]		√	√			√	√				√	√			Geospatial based fuzzy overlay technique
	28	25	22	12	10	12	13	10	5	7	13	9	12	3	

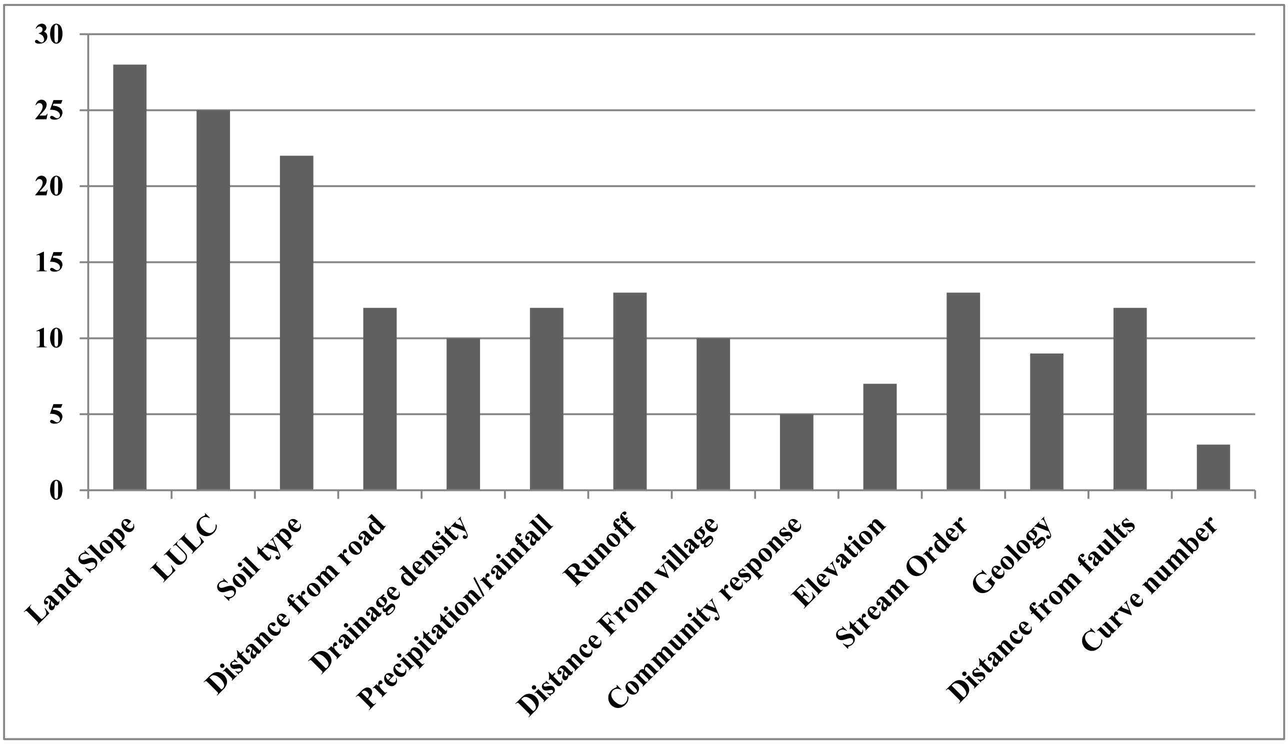

Fig. 1. The fourteen criteria used for the dam site selection presented over the collected literature review.

communities. To address these issues of a complex and subjective nature, decision makers use techniques like Boolean Methods and Fuzzy Systems. Such tools are applied appropriately to process qualitative data and conduct a detailed analysis, which is imperative to the varied community viewpoints and detailed environmental assessment.

Figure 2 below enumerates the distribution of MCDM techniques employed for dam site selection, reflecting a detailed account of methodological preferences in environmental and infrastructure projects. The majority of the pie chart is covered by AHP, with 50% of the applications, thereby shaping the crux of the methodology in complex decision-making structures. The popularity of the AHP technique is due to its ease in blending quantitative and qualitative assessments, which is necessary to govern the spectrum of project imperatives. Fuzzy Logic, at 14% of the usage, performs extremely well in environments with high uncertainty and imprecision, which are typical of environmental impact evaluations, where data are likely to overlap or be ill-defined; thus, it succeeds in the interpretation of subtle environmental data. Still, WLC, which at 19% of the applications, is praised for the adaptability in weighting criteria, that is, the prioritization of criteria may be customized to the specific needs of the project, and thus, the scope for decision-making can be tailored accordingly; other methods, such as Boolean Methods and TOPSIS, though very niche in proportion, reflect their usage in specific scenarios where the need for specific analytical capabilities is required. These roles reflect the robust toolkit available to the decision-makers, who can tailor their strategies for the unique challenges of a project, and thereby ensure the best decision-making framework for dam site selection.

The relationship between the frequency of criteria usage and the diversity of applied methodologies in MCDM for dam site selection are discussed in Table 4 below. The strategic adaptive approach of MCDM techniques is further underlined because, more often than not, criteria that are most taken into account in different studies present a wider array of methodologies applied in their analysis. This implies a strong framework that seeks to ensure very comprehensive evaluation on a diversity of analytical perspectives, which in reality is crucial to capture numerous impacts and interactions that intervene in dam site selection.

As for the selection of the sites, the criteria Land Slope and Soil Type, the critical two most important elements for the assessment of feasibility and safety of the dam projects, exhibit high frequencies in use and are analyzed with multiple methodologies. The multiple methodological approaches in understanding such critical factors add to the enhanced depth and

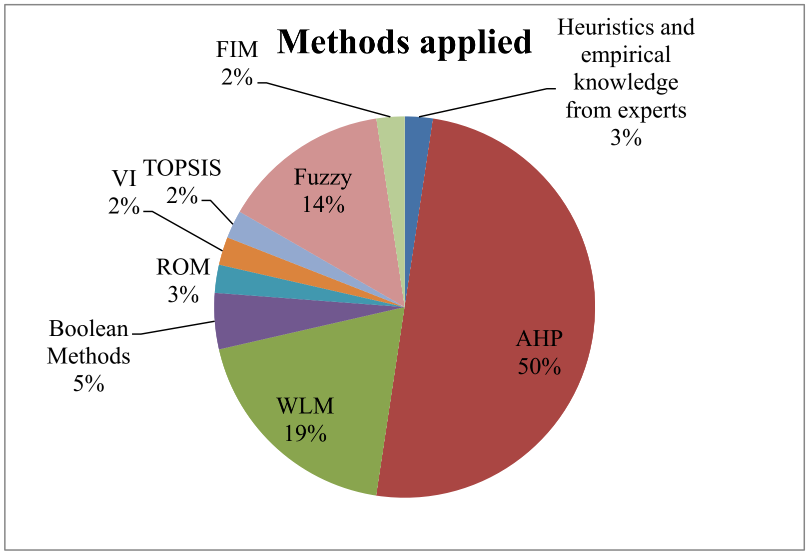

Fig. 2. The percentages of the applied methods for the collected literature review on dam site selection.

Table 4. Criteria usage vs. methodological diversity.

Criteria	Frequency of criterion used	Number of techniques applied
Land Slope	28	9
LULC	25	9
Soil type	22	9
Distance from road	12	6
Drainage density	10	3
Precipitation/rainfall	12	3
Runoff	13	6
Distance from village	10	6
Community response	5	4
Elevation	7	3
Stream Order	13	5
Geology	9	4
Distance from faults	12	5
Curve Number	3	3

reliability of the process of site selection. Bringing diversity in methodologies, from quantitative tools such as AHP to qualitative assessment using Fuzzy Logic, the whole process of analysis gets broadened in accordance with the data that is measurable and expert judgment, thus reflecting a balance and inform process of making decisions.

6. Conclusion and recommendation

Multi-criteria decision-making methods are critical in selecting a dam site through the balancing and integration of both quantitative and qualitative factors, such as those concerning environmental, socio-economic, and technical factors, to facilitate sustainable construction practices. The MCDM methods include analysis of the AHP, WLC, and the TOPSIS methodologies, which have been reputed for global use and acceptance in dealing with the complexities involved in dam site selection. In other words, through these methods, it is possible to exercise thorough evaluations that balance development objectives with conservation imperatives. Integration of GIS with MCDM further helps in the visualization and analysis of key factors affecting dam site selection, including but not limited to topography, hydrology, geology, environmental, and socio-economic considerations. This will be helpful in informed and scientifically right decision-making. Consequently, detailed checking of criteria in the form of charts and graphs allows one to see all patterns and intricacies defining the chosen sequence and, therefore, represents the multidimensional nature of dam site selection. The conclusion of this study, thus, recommends that the MCDM techniques find further use and improvement in the site selection of dams. Future research is supposed to be with more concentration on putting into consideration improved analytical tools in the procedure for enhancing better methods. The engagement of stakeholders on the part of local communities and environmentalists alike must also be improved. This will ensure that the selection of dam sites is attained in order to meet a scope of wider ecological, economic, and social goals with a balanced approach, not only to meet immediate needs but also to consider long-term sustainability and environment protection.

List of abbreviation

MCDM: Multi-Criteria Decision Making; ELECTRE: Elimination and Choice Translating Reality; AHP: Analytical hierarchy process; DEMATEL: Decision Making Trial and Evaluation Laboratory; TOPSIS: Technique for Order Preference by Similarity to an Ideal Solution; PROMETHEE: Preference Ranking Organization Method for Enrichment Evaluations; ANP: Analytic Network Process; WLC: Weighted Linear Combination; ROM: Rank Order Method; VI: Variance Inverse; FIM: Factor Interaction Method; MCE-GIS: Multi-Criteria Evaluation Geographic Information System.

Conflict of interest

The authors declare no conflict of interest to any party.

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