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Evaluating Environmental Impacts of Dam Construction Using an Enhanced Quantitative Checklist: A Case Study of Haleh Dam in Iran

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Abstract

The construction of dams, as one of the fundamental strategies for water resources management, has always been accompanied by environmental challenges. This study conducts a comprehensive environmental impact assessment (EIA) of the Haleh Dam located in Kuhdasht County, Lorestan Province, Iran. The methodological approach integrates a quantified checklist with the modified Iranian Leopold matrix to enable a precise and comparative analysis of impacts during both construction and operation phases. Evaluations were performed based on three criteria—significance, intensity, and nature of effects—across four environmental dimensions: physical, biological, socio-economic, and cultural.

The findings indicate that during the construction phase, the implementation scenario (−146) demonstrated a relatively lower adverse impact compared to the non-implementation scenario (−160), while the operation phase (+378) revealed long-term positive effects mainly in the socio-economic dimension (+155), such as improved water supply, flood regulation, and job generation. Nevertheless, several components, particularly terrestrial habitats and surface water quality, experienced moderate to high negative impacts during construction.

Therefore, the study suggests that the Haleh Dam may be considered environmentally justifiable, conditional upon the effective implementation of mitigation and monitoring measures. It also acknowledges inherent methodological limitations, including reliance on expert judgment for scoring and the lack of post-implementation monitoring data. Despite these constraints, the proposed integrated approach provides a practical framework for EIA in data-limited contexts and can support sustainable assessment of similar water infrastructure projects in developing regions.

Introduction

In recent decades, pressures stemming from population growth, industrial expansion, shifting consumption patterns, and climate crises have compelled governments and societies to develop extensive plans for vital infrastructure, particularly in the domain of water resources. Among these, dam construction projects have played a crucial role as a key instrument in water resource management, contributing to potable water supply, flood control, hydropower generation, and agricultural support (World Commission on Dams, 2000; Ansar et al., 2014). However, the vast scale and complexity of such projects have rendered them among the most controversial forms of human intervention in nature. Although dams offer benefits, they can cause significant ecological, social, and economic impacts, which has led to the global

adoption of Environmental Impact Assessment (EIA) to guide sustainable project decisions (Fearnside, 2016; Lerer and Scudder, 1999).

The primary objective of EIA is to identify, predict, and analyze the direct and indirect impacts of proposed projects on environmental components prior to implementation. It aims to reduce environmental damage and optimize the socio-economic benefits of projects by proposing corrective and mitigation strategies (Glasson et al., 2013; Canter and Wood, 1996). EIA has not only become a tool for environmental protection but has also evolved into an integral part of development policy-making (Morgan, 2012; Pope et al., 2013).

In Iran, EIA studies officially started in the mid-1990s after the ratification of relevant regulations (Makhdoum, 2008). However, experiences from several dam projects, including Karkheh, Gotvand, Sivand, and Karun-4, show that merely following the administrative EIA process does not ensure impact mitigation or sustainable development (Makhdoum, 2008; Khodabakhshi et al., 2011). Common shortcomings include weak methodological design, neglect of cumulative impacts, limited stakeholder engagement, and lack of post-implementation monitoring, all of which reduce assessment effectiveness (Bragagnolo et al., 2017; Sánchez and Morrison-Saunders, 2011). Dam construction projects require rigorous and multidimensional analysis. Their impacts occur in two main phases: construction and operation. The construction phase often causes temporary but severe effects, such as vegetation loss, noise pollution, geomorphological changes, and threats to wildlife. The operation phase, however, leads to longer-term consequences, including altered flow regimes, water quality degradation, species loss, and persistent social impacts (World Commission on Dams, 2000; Lyu et al., 2018). Therefore, the use of integrated and quantitative EIA tools is essential.

Traditional EIA methods such as simple checklists, the Leopold matrix (1971), and qualitative forms while straightforward, lack the ability to prioritize and quantify impacts and are often influenced by subjective judgments of evaluators (Sadler and Verheem, 1996). In Iran, some dam construction projects have also employed these traditional approaches, such as the ICOLD and Leopold matrices. For instance, in the study by Sayadi et al. (2009) on the Gotvand Dam, a combination of the ICOLD and Leopold matrices was applied to assess environmental impacts across three domains: physico chemical, biological, and socio–cultural. The results indicated that although the applied method was effective in identifying a broad spectrum of environmental impacts, it lacked quantitative weighting and prioritization among various effects, thereby limiting the precision of stepwise decision-making. Moreover, the authors emphasized the necessity of integrating Geographic Information System (GIS) data and local participation to enhance the reliability of results. These findings highlight the inherent limitations of traditional matrix-based EIA methods and underscore the need for adopting more quantitative and scored approaches in environmental impact assessment. Likewise, the environmental assessment of the Zhaveh Dam in western Iran (Karimi et al., 2019) employed both the checklist and ICOLD matrix approaches to evaluate the project's biophysical and socio-economic impacts. The results indicated that while the ICOLD matrix identified broad environmental categories, it remained largely descriptive and lacked any systematic weighting or prioritization of parameters. Similarly, the checklist method could detect direct and indirect biological impacts, but its qualitative and non-comparative nature prevented an integrated evaluation of the project's overall environmental condition. The study concluded that both approaches failed to provide a transparent basis for decision-making or to capture cumulative, long-term effects. Such methodological deficiencies, consistent with those observed in the Gotvand Dam case (Sayadi et al., 2009), reinforce the necessity for a more quantitative, structured, and rank-based checklist such as the one proposed in the present study to improve the reliability, traceability, and reproducibility of EIA

outcomes for large dam projects. To address these limitations, researchers have increasingly turned to advanced approaches such as scoring-based checklists, the modified ICOLD matrix, Analytical Hierarchy Process (AHP), multi-criteria decision-making (MCDM) models, and the integration of spatial data (GIS) to support more evidence-based and precise decision-making processes (Geneletti, 2005; Modak and Biswas, 1999; Dehnavi and Kouzehgar, 2019).

Recent advances in multi-criteria decision-making (MCDM) have expanded the methodological rigor of dam-related environmental assessments through hybrid weighting and ranking schemes that balance objective and subjective inputs. For instance, Eslami et al. (2021) applied the IDOCRIW–COCOSO framework to evaluate and prioritize mitigation strategies for the Nohob Dam (Iran), achieving improved balance between entropy-based weights and expert judgment. While such approaches reduce bias in criteria weighting, integration of cumulative impacts and post-2020 adaptive monitoring indicators within a unified GIS-MCDM workflow remains limited a gap addressed in the present study for the Haleh Dam.

One Emerging framework in this domain is the use of quantified checklists incorporating indicators such as intensity, spatial extent, reversibility, duration, likelihood, and interaction with other impacts. These allow for better prioritization of negative impacts and identification of mitigation actions (Valizadeh and Shekari, 2015). Additionally, matrix-based methods especially in localized versions such as the Iranian modified matrix have gained traction due to their flexibility and adaptability to dam construction projects in Iran (Javadi et al., 2007; Valizadeh and Shekari, 2015). By combining these two methods, it becomes possible to achieve a more comprehensive assessment of project impacts across different time periods and domains including physical, biological, economic, and social aspects. It is noteworthy that in addition to environmental impacts, the social and cultural dimensions of dam projects have gained increasing attention. Neglecting human-related issues such as forced displacement, disruption of local livelihoods, social dissatisfaction, and erosion of community cohesion can significantly affect the overall effectiveness of a project (Mostert, 2003; Lerer and Scudder, 1999). Therefore, effective EIA studies must transcend a purely environmental perspective and move toward an interdisciplinary framework that actively involves stakeholders.

Unlike previously reported hybrid approaches such as the ICOLD Leopold combination, AHP, MCDM, or GIS-based assessments, the present integration was specifically designed to preserve the operational simplicity of a quantified checklist while incorporating the multi-dimensional analytical capacity of the Iranian modified Leopold matrix. This design eliminates the need for complex hierarchical weighting or extensive spatial datasets, making it particularly effective for large dam projects in data-limited contexts. Moreover, it allows scoring at the activity component interaction level, which directly supports prioritization of impacts and selection of mitigation measures a capability not explicitly addressed in earlier hybrid models.

In this context, the present study adopts a combined framework of scoring-based checklists and the Iranian modified matrix to offer a structured, quantitative, and localized methodology for assessing the environmental impacts of a dam construction project. The model evaluates the effects of each project activity during both construction and operation phases on key environmental components including water quality, vegetation cover, wildlife habitats, soil resources, and socio-economic sustainability. By employing a criteria-based scoring system and comparing the scenarios of implementation versus non-implementation, the approach provides a decision-making platform grounded in comparable and evidence-based data. In this study, the approach referred to as the "Advanced Checklist" is not intended as an entirely new framework but rather as a methodological enhancement of the quantified checklist technique. Three additional evaluation criteria importance (I), magnitude (M), and nature (N) of the impacts were

incorporated, and the scoring logic of the Iranian Modified Leopold Matrix was systematically integrated into the checklist structure. This incremental improvement maintains the quantitative simplicity of the original checklist while enriching it with analytical depth, localization, and multidimensional interpretability for dam-related environmental impact assessments in Iran.

Ultimately, the selection of the advanced checklist method in this study is driven by the need to integrate analytical rigor, ease of application, tool localization, and result interpretability. The findings of this research are expected not only to provide an objective assessment of the case study project, but also to serve as a replicable model for conducting EIA in other dam construction projects in Iran, especially in ecologically and hydrologically sensitive areas.

Materials and Methods

This study evaluates the environmental impacts of the Haleh Dam construction project, located in Kuhdasht County, Lorestan Province, Iran. Considering the significance of dam construction in securing water resources and promoting sustainable development, the need for systematic and efficient assessment approaches in this region was evident. Accordingly, an integrated methodology combining a quantified checklist and the Iranian-modified Leopold matrix was selected to perform a comprehensive Environmental Impact Assessment (EIA). The objective of this study is to provide an interpretable and holistic picture of the environmental impacts across the various phases of the project namely construction and operation.

Study Area

Haleh Dam is situated in Kuhdasht County, Lorestan Province, Iran, approximately 12 kilometers from the city center, at geographic coordinates of approximately 47°35′ E and 33°25′ N. Nestled within the Zagros Mounta ins, the surrounding region is renowned for its pristine natural landscapes, scenic valleys, and ecological richness, making it a popular local ecotourism destination. The dam area encompasses the catchment basins of the Madianrud River and the Darreh-Dezdan Valley, both of which play a crucial role in regional water management and development. From an engineering perspective, Haleh Dam is a homogeneous earth-fill structure with a maximum height of 44 meters and a total reservoir volume of 3.5 million cubic meters, while its regulated water storage capacity reaches approximately 7.2 million cubic meters. The irrigation command area and associated water distribution networks cover roughly 250 hectares, contributing significantly to local water resource utilization and management. The dam is critical for agricultural water supply, flood control, and the protection of natural resources in the region. Additionally, it provides opportunities for recreational activities, aquaculture development, and broader economic growth. Balancing ecological integrity with economic exploitation is of particular importance in this context. As a vital infrastructural investment in the domains of water and environmental management, the construction of Haleh Dam also serves as a key driver for sustainable development, improving the quality of life and supporting regional economic progress. Preliminary estimates indicate that the dam can annually provide around 5 million cubic meters of water for agricultural use, enabling irrigation of approximately 500 hectares of farmland. This has already contributed to the expansion of agricultural and industrial activities, facilitated flood control, enabled land reclamation, and fostered fish farming and tourism development. The region’s semi-arid climate, coupled with its diverse flora and fauna, increases the ecological vulnerability of the ecosystem. From a socio-economic perspective, local communities largely rely on natural resources, agriculture, and animal husbandry. For the purpose of environmental assessment and analysis, data were collected through a combination of approaches, including literature review, existing technical reports, field surveys, and interviews with experts and local stakeholders. Fig. (1) Illustrates the geographical location of Haleh Dam within Lorestan Province.

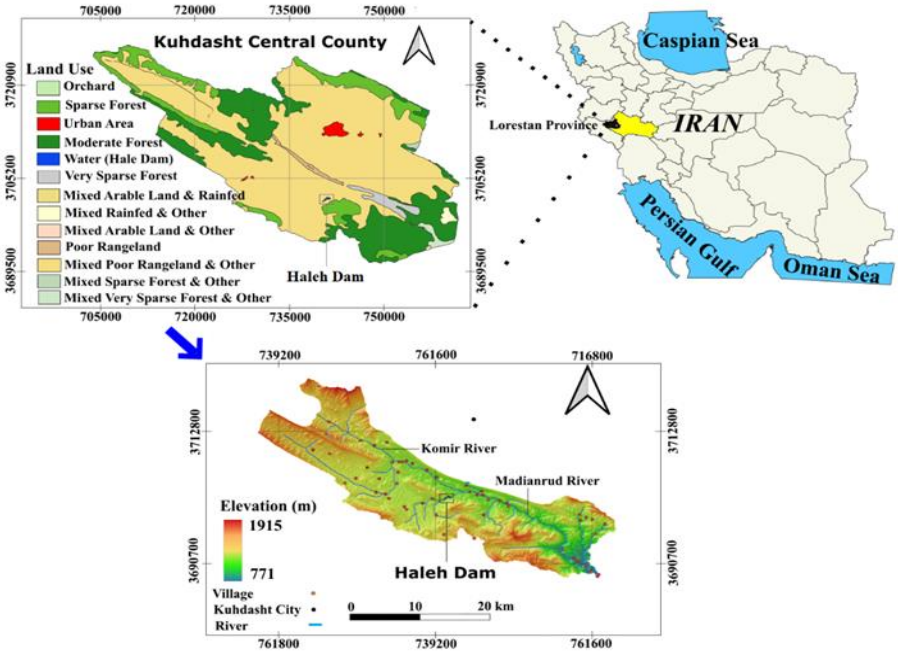


Fig. 1- Geographical location of the Hale Dam – Kohdasht, Lorestan, Iran.

Scoring Methods Quantified Checklist Method

In the process of environmental impact analysis, the initial stage aimed to identify, categorize, and prioritize potential interactions between project activities and various environmental components. For this purpose, the quantified checklist method was used to convert qualitative observations into numerical values. This method provides a structured and comparable analysis and serves as a practical tool, especially during the screening phase and for stakeholder engagement. Within this method, all potential interactions between project activities and environmental components were systematically assessed. These interactions were evaluated using a set of key indicators and quantitative criteria designed to express the relative weight and significance of each impact within the overall assessment process.

Scoring Framework

At this stage, for each specific interaction between a project activity and an environmental component, a set of evaluation metrics was defined based on three primary and essential indicators. The first indicator, Importance of Effect (I), reflects the relative weight and significance of each impact on a numeric scale from 0 to 5. This score plays a pivotal role in prioritizing environmental effects and enables decision-makers to focus on more critical and influential impacts in the Mitigation and management process. The second indicator, Magnitude of Effect (M), quantifies the extent or potential severity of the impact that each activity may exert on a given environmental component. It is assessed on a scale from 1 to 3, with higher values indicating stronger and more substantial effects. The third indicator, Nature of Effect (N), denotes the direction and type of the impact. Positive impacts are assigned a score of +1, while negative impacts are given a value of −1. This indicator allows for a combined analysis of both beneficial and adverse project outcomes within a single integrated framework. The final score for each interaction is calculated and recorded using Equation (1):

$$\text{Score} = \text{Importance of Effect (I)} \times \text{Magnitude of Effect (M)} \times \text{Nature of Effect (N)} \quad (1)$$

Equation (1) essentially applies a weighting mechanism to the core indicators, expressing

the degree of influence of each interaction as a function of its importance, magnitude, and nature. This composite scoring system forms a foundational reference for subsequent analyses and for constructing the project's environmental impact matrices.

Data Collection and Expert Consultation

To ensure the accuracy and reliability of the evaluation results, data were collected through structured questionnaires distributed among 36 domain experts involved in the study. The panel included six experts from the Regional Water Authority, four from the Water and Wastewater Company, nine agricultural specialists, four environmental experts, six structural civil engineers, two university professors specializing in structural engineering, and five hydraulic engineers focusing on water structures The mean of all expert scores was used to determine the final quantitative values applied in the matrices All expert opinions were assigned equal weight, while the views of local stakeholders were incorporated qualitatively, based on field observations and semi-structured interviews conducted within the project area. Experts were selected purposively based on their direct experience in environmental impact assessment and dam construction projects, with a minimum of five years of professional background in related fields. The selection aimed to include a balanced representation of governmental, academic, and private-sector perspectives to minimize disciplinary bias and ensure methodological rigor. Prior to data collection, a short calibration session was organized to ensure a common understanding of each evaluation criterion and scoring scale among all experts. Significant discrepancies in individual scores were reviewed through group discussion, and the mean values were adopted as the final quantitative inputs to minimize evaluator bias and enhance scoring consistency.

Activities and Environmental Components Assessed

In the process of environmental impact assessment, the main activities and operations during both construction and operation phases of the project were identified and listed. These included: earth excavation and soil compaction, construction of access roads, heavy machinery operations and mechanized activities, generation of construction and industrial waste, development of green spaces and restoration of natural habitats, as well as the presence and behavior of the workforce at the project site. Each of these activities was evaluated in relation to four principal and critical environmental dimensions: the physical dimension, including land, water, and air; the biological dimension, comprising vegetation cover and wildlife; the socio-economic dimension, encompassing employment, migration, livelihoods, and regional economic development; and finally, the cultural dimension, which addressed cultural heritage, natural landscape, and social interactions within the local community. This assessment served as a foundation for deeper and more structured analyses in the subsequent stages of the evaluation process, and played a significant role in identifying key impacts and prioritizing environmental management actions.

Modified Iranian Leopold Matrix

In the subsequent step, to conduct a more structured and multidimensional analysis of environmental impacts, a localized version of the Leopold Matrix was employed. Originally introduced in 1971 by Leopold, this tool was adapted in the present study to better suit the climatic, ecological, and socio-cultural conditions of Iran, based on the modifications proposed by Makhdoum (2008). The primary objective of this adaptation was to establish an analytical framework capable of assessing project impacts more accurately and effectively within local and regional contexts.

Structure and Characteristics of the Matrix

The modified Leopold Matrix employed in this study adopts a two-dimensional structure, wherein the rows represent the main project activities and the columns denote various environmental components. Within each cell of the matrix, the indicators of importance, magnitude, and nature of impact are recorded

based on the results of prior assessments. This flexible structure allows for the evaluation of direct, indirect, cumulative, and long-term impacts of the project. Notably, the scoring range in this adapted version is confined to ±5, in order to facilitate a more intuitive and locally ontextualized interpretation of the results at both local and regional scales. Moreover, due to the critical relevance of long-term and cumulative effects in large-scale infrastructure projects, special attention was given to indirect impacts and background interactions, such as pollutant dispersion, ecological shifts, and transport-induced effects, throughout the assessment process.

Integrated Approach: Advanced Checklist

In light of previous approaches, both the Quantified Checklist and the Modified Leopold Matrix have been recognized for their respective advantages and limitations. While the checklist method will facilitate simplicity and the numerical representation of impacts, it will remain constrained in delivering a comprehensive and multi-dimensional evaluation. Conversely, the Leopold matrix will enable more structured and multi-dimensional interpretations but may initially exhibit certain structural shortcomings. To address these limitations and to harness the strengths of both methods, an integrated approach, hereafter referred to as the "Advanced Checklist", is introduced as an incremental methodological improvement over the quantified checklist method. This hybrid approach will combine the simplicity and quantifiability of the checklist with the multi-dimensional and structured analysis offered by the Leopold matrix. In implementing the integrated framework for environmental impact assessment of the project, five critical stages will be followed, each playing a vital role in structuring and deepening the analytical process. First, the key project activities across the construction, operation, and upgrading phases will be identified and listed. These activities will then be classified according to four principal environmental dimensions: physical (land, water, air), biological (vegetation, wildlife), socio-economic (employment, migration, livelihoods, regional development), and cultural (cultural heritage, natural landscape, and local community interactions). Subsequently, the potential interactions between each activity and the environmental components will be assessed and scored based on the three criteria: importance (I), magnitude (M), and nature (N) of the impact. These assessments will serve as the foundation for more detailed and comprehensive analyses in subsequent stages. Thereafter, the final score for each interaction will be calculated using the numerical expression: $I \times M \times N$, enabling a structured and quantitative depiction of each activity's level of impact on different components.

The results will then be organized into two-dimensional matrices, where the aggregate scores corresponding to each activity and component will be determined, thereby identifying critical patterns and impact hotspots. In the final stage, two practical scenarios "Project Implementation" and "No-Action" will be designed and formalized to facilitate comparative analysis and informed strategic decision-making. Although numerical analyses of these scenarios will not yet be executed at this stage, the necessary infrastructure for such advanced evaluations will have been thoroughly established and will be ready for future use.

This integrated approach will preserve both simplicity and numerical capacity while enabling comprehensive, multi-dimensional impact analyses. Moreover, the method will enhance the precision and Efficiency of the evaluation process and allow for the identification of complex relationships and indirect project effects. It will empower managers and decision-makers to better understand project impacts across various spatial and temporal scales and adopt appropriate strategies for mitigating adverse consequences.

Additionally, the approach will provide a robust foundation for developing quantitative models, long-term predictions, and sensitivity analyses throughout the planning and implementation phases-ultimately contributing

to the effective and sustainable management of environmental projects.

In conclusion, this intelligent and precise integration of methods and tools will offer a comprehensive, flexible, and locally adaptable framework with a critical role in the holistic management of environmental project impacts. It will not only support a deeper and clearer understanding of environmental effects but also promote a transparent, evidence-based decision-making process ultimately leading to sustainable project development in harmony with the environment.

Findings

In this study, a hybrid advanced checklist framework was utilized to conduct a Quantitative analysis of the environmental impacts resulting from the implementation of the Haleh Dam project. To this end, numerical values assigned to each interaction between project activities and environmental components were calculated, and the algebraic sum of the scores in each column of the matrix was derived and recorded for the four principal environmental dimensions: physical, biological, Socio-economic, and cultural. This methodology enabled a structured, data-driven, and comparative evaluation of the impacts and provided a solid foundation for interpreting the detailed findings across the construction and operational phases of the project.

Environmental Impact Assessment during the Construction Phase

To conduct a precise and quantitative analysis of the environmental impacts associated with the construction phase of the Haleh Dam project, a structured and enhanced-format table was utilized. This table systematically evaluates the effects of each construction activity based on four main environmental dimensions: physical, biological, socio-economic, and cultural Table (1). It is built upon data derived from the advanced scoring checklist model and enables a comparative and analyzable quantitative representation of the ecosystem status, providing insight into both favorable and adverse impacts of various development activities. The findings from this stage indicate that, within the physical dimension, activities such as excavation and embankment, workshop construction, and the operation of heavy machinery exert the most significant negative impacts on the environment. These adverse effects, clearly reflected in the negative numerical scores in Table 1, primarily degrade soil quality, air conditions, and surface water resources. Subsequent assessments of the other environmental dimensions followed the same analytical framework, with the results presented in Table (2). In the biological dimension, wastewater generation, excavation and embankment, and the construction of access roads were identified as major sources of negative impact, whereas actions such as green space development and vegetation restoration showed considerable positive effects. In the socio-economic dimension, most activities were found to yield beneficial outcomes, including the creation of temporary employment, increased economic interactions, and improvement of local infrastructure. Within the cultural dimension, the construction of access roads enhanced connectivity to cultural and historical areas, although extensive excavation and wastewater discharge had detrimental effects on the natural landscape and cultural heritage of the region. Tables (1) and (2) collectively provide a comprehensive overview of the environmental consequences during the construction phase, serving as a foundation for the comparative analysis of project implementation versus non-implementation scenarios in the subsequent section.

Analysis of the Implementation and Non-Implementation Scenarios during the Construction Phase

The findings derived from Table 2 indicate that the total environmental impact score associated with construction-related activities of the Haleh Dam project, within the physical dimension, amounted to −146. This figure reflects the substantial negative effects of activities such as excavation, material transport, and the operation of heavy machinery on the physical integrity of the

regional ecosystem. Subsequently, the cumulative environmental impact assessment was conducted across the four principal dimensions physical, biological, socio-economic, and cultural for two scenarios: "project implementation" and "project non-implementation" during the construction phase. The results yielded total scores of −146 and −160, respectively Fig. (2). The relatively small difference between the two scenarios suggests that, while the regional ecosystem is affected by human interventions in both cases, project implementation offers greater potential for environmental management and mitigation through targeted strategies. Notably, many of the adverse effects associated with the non-implementation scenario stem from the persistence of pre-existing unfavorable conditions, including destructive flooding events, limited economic development, and weak local infrastructure. In contrast, project implementation despite initial environmental costs can be accompanied by structured monitoring programs and mitigation measures, making the impacts more manageable. Therefore, from a strategic perspective, the implementation scenario is more defensible. It allows for the control, reduction, and possible compensation of negative impacts, whereas the non-implementation scenario risks the continuation of chronic, unmanaged environmental threat.

Table 1- Assessment of environmental impacts in the physical environment, construction phase

Activities	Excavation and backfilling				Establishment of workshop equipment				Operation of machinery				Construction of access road				Solid waste generation			
Environmental parameter	I	M	N	effect	I	M	N	effect	I	M	N	effect	I	M	N	effect	I	M	N	effect
Air quality	4	3	-	-12	3	2	-	-6	3	3	-	-9	2	2	-	-4	2	2	-	-4
Ambient noise	3	3	-	-9	3	2	-	-6	3	3	-	-9	2	2	-	-4	0	0	0	0
Surface water quality	2	1	-	-2	2	1	-	-2	1	1	-	-1	1	1	-	-1	2	3	-	-6
Landform	4	3	-	-12	3	3	-	-9	3	3	-	-9	2	2	-	-4	0	0	0	0
Soil erosion	4	3	-	-12	3	3	-	-9	3	2	-	-6	2	3	-	-6	0	0	0	0
Cumulative effect				-47				-32				-34				-19				-10

$$\sum(I \times N \times M) = -142$$

Table 2- Summation of the environmental impact assessment of Haleh Dam during the

Activities	Physical					Biological					Socio-economic			Cultural		
Environmental parameter	Excavation and backfilling	Establishment of workshop equipment	Operation of machines	Construction of access road	Solid waste production	Excavation and backfilling	Construction of access road	Creating green space	Establishment of workshop equipment	Solid waste production	Hiring a worker	Construction of access road	Creating green space	Solid waste production	Construction of access road	Excavation and backfilling
Air quality	-12	-6	-12	-4	-4	0	0	0	0	0	0	0	0	0	0	0
Ambient noise	-9	-6	-9	-4	0	0	0	0	0	0	0	0	0	0	0	0
Surface water quality	-2	-2	-1	-1	-6	0	0	0	0	0	0	0	0	0	0	0
Landform	-12	-9	-6	-4	0	0	0	0	0	0	0	0	0	0	0	0
Soil erosion	-12	-9	-6	-6	0	0	0	0	0	0	0	0	0	0	0	0
Plant habitat	0	0	0	0	0	-6	-4	+12	-4	-4	0	0	0	-6	+6	-4
pest insects	0	0	0	0	0	-4	-4	+9	-4	-4	0	0	0	0	+4	0
Creepy crawlies	0	0	0	0	0	0	0	0	-1	-6	0	0	0	-4	0	-9
Income and expenses	0	0	0	0	0	0	0	0	0	0	+9	+6	+1	0	0	0
Transportation	0	0	0	0	0	0	0	0	0	0	-4	+9	0	0	0	0
Employment	0	0	0	0	0	0	0	0	0	0	+12	0	+1	0	0	0
Agriculture	0	0	0	0	0	0	0	0	0	0	-4	-1	0	0	0	0
Algebraic sum of effects	-47	-32	-34	-19	-10	-10	-8	+21	-9	-14	+13	+14	+2	-10	+10	-13
Total values	-142					-20					+29			-13		

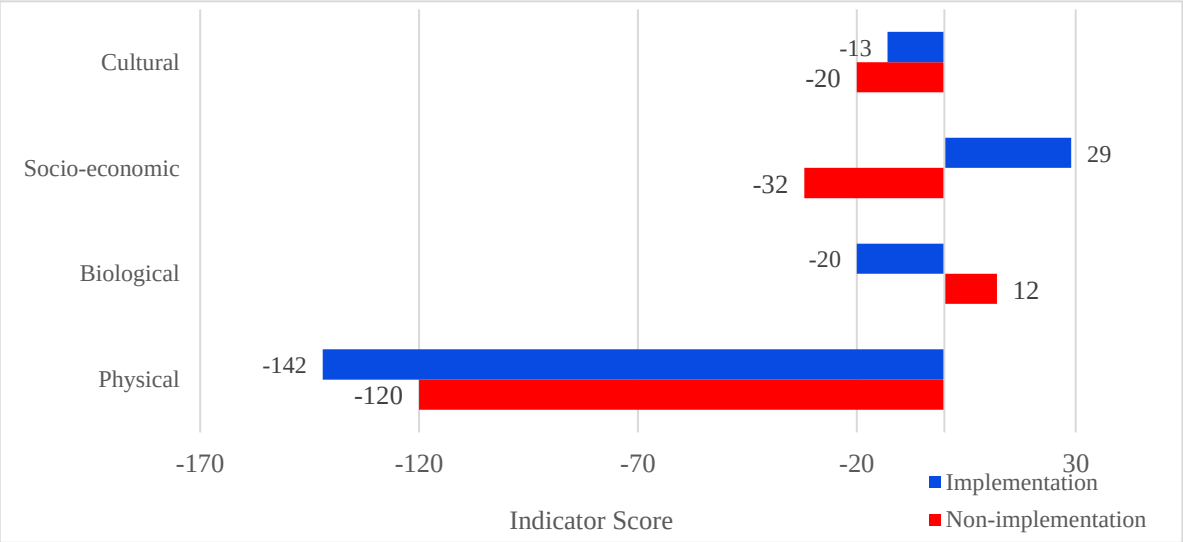


Fig. 2- Implementation and Non-Implementation Options for the Project during the Construction Phase

Environmental Impact Assessment during the Operational Phase

During the operational phase of the Haleh Dam, the environmental impact assessment summarized in Table (3) yields a total cumulative score of +378, indicating a net positive effect of the project on the surrounding ecosystem and various environmental dimensions. A detailed analysis of the results reveals that the socio-economic environment experienced the most substantial positive impact, with a cumulative score of +155, highlighting the project's significant contribution to regional development and improved well-being. Within the socio-economic dimension, activities such as water supply, flood control, development of recreational areas, maintenance of access roads, and green space management generated the highest positive impacts. The provision of water led to population growth, job creation, adequate supply for agriculture, drinking, and industrial use, land-use change from rain-fed to irrigated farming, and overall enhancement of social welfare. Additionally, flood control contributed to the protection of agricultural lands, reduced soil erosion, and minimized economic losses resulting from flood events. The development of recreational facilities facilitated tourism, sports, and leisure activities centered on the reservoir.

In the cultural dimension, despite some negative effects associated with increased chemical fertilizer use, the overall score reached +92. Key positive outcomes included improved public health indicators, enhanced scenic landscapes, and promotion of tourism, made possible by improved water access and the expansion of cultural-recreational amenities.

The physical environment also recorded a net positive impact of +84, despite some adverse effects due to agricultural chemical inputs. The most notable positive impact was related to flood control, which led to reduced erosion, improved surface water quality, and protection of agricultural productivity. Additionally, water provision facilitated the conversion of dryland to irrigated farmland, while green space maintenance improved air quality and further reduced soil degradation.

In the biological dimension, a total of +47 positive impacts were identified. The primary contributors were, respectively, water provision, flood control, and green space maintenance. Water availability promoted the restoration of plant and animal habitats and encouraged the return of wildlife species. Flood control enhanced ecological resilience, and green space conservation not only improved air quality but also supported vegetation preservation in the region.

Analysis of Implementation and Non-Implementation Options during the Operational Phase

According to the findings summarized in Table (3), the total cumulative score from the environmental impact assessment during the operational phase of the Haleh Dam across the four key dimensions (physical, biological, socio-economic, and cultural) amounts to +378, reflecting the predominance of positive environmental impacts resulting from the dam's operation. In contrast, the hypothetical scenario of "non-implementation of the project" during the same phase yields a cumulative negative score of –360. A comparative analysis of these two scenarios implementation versus non-implementation is illustrated in Fig. (3), clearly demonstrating that the operational phase of the project has yielded substantial positive impacts, particularly in terms of enhancing socio-economic indicators and mitigating adverse physical and biological effects. These results strongly support the necessity of implementing the project, provided that environmental requirements are observed and continuous monitoring is conducted throughout the operational period.

Final Evaluation of Implementation and Non-Implementation Options across the Construction and Operational Phases

To provide a more comprehensive assessment of the project's impacts, a comparative analysis was conducted between the implementation and non-implementation scenarios across both the construction and operational phases. The outcomes, illustrated in Fig. (4), reveal significant differences between the two alternatives across various environmental dimensions:

- In the physical environment, project implementation resulted in a total of –58 negative impacts, whereas the non-implementation scenario projected a far higher magnitude of –200 negative effects. This indicates that, while the project introduces some adverse effects, it effectively mitigates the severity of naturally occurring environmental degradation.
- In the biological environment, implementation yielded a positive score of +27, while non-implementation corresponded to –28, underscoring the project's ecological restoration benefits.
- In the socio-economic environment, the contrast is particularly significant: implementation led to +184 positive impacts, in stark contrast to –202 negative impacts under the non-implementation scenario highlighting the project's critical role in enhancing livelihoods, employment, and water security.
- In the cultural environment, the project contributed to +79 positive impacts, compared to –90 under the non-implementation case.

Ultimately, the aggregate assessment across both phases demonstrates a total of +232 positive effects for the implementation option, versus –452 negative effects for non-implementation. These findings clearly affirm that, despite some temporary adverse effects associated with project development, its overall contribution to sustainable regional development and mitigation of latent environmental risks strongly justifies its execution.

Table 3- Summary of the Environmental Impact Assessment during the Operational Phase of the Haleh Dam

Activities	Physical				Biological			Socio-economic					Cultural					
Environmental parameter	Water supply	Flood control	Fertilizer usage	Green space maintenance	Water supply	Flood control	Green space maintenance	Water supply	Flood control	Recreational development	Green space maintenance	Access road maintenance	Water supply	Flood control	Recreational development	Fertilizer usage	Green space maintenance	Access road maintenance
Air quality	0	0	0	+10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface water quality	+12	+9	-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upstream groundwater quality	+4	+4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater quality	+4	+6	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low-flow regime	+4	+6	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flood regime	+6	+6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landform	0	+2	-1	+4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soil erosion	0	+9	-4	+15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plant habitat	0	0	0	0	+9	+9	+4	0	0	0	0	0	0	0	0	0	0	0
Animal habitat	0	0	0	0	+9	+9	+4	0	0	0	0	0	0	0	0	0	0	0
Pest insects	0	0	0	0	0	-6	0	0	0	0	0	0	0	0	0	0	0	0
Animal migration	0	0	0	0	+9	+4	+1	0	0	0	0	0	0	0	0	0	0	0
Population of the area	0	0	0	0	0	0	0	+15	+6	+6	+1	+1	0	0	0	0	0	0
Employment	0	0	0	0	0	0	0	+12	+4	+4	0	+9	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0	+15	+12	0	0	+1	0	0	0	0	0	0
Land use	0	0	0	0	0	0	0	+9	+12	+4	0	+4	0	0	0	0	0	0
Income and expenditures	0	0	0	0	0	0	0	+9	+12	+9	+1	+6	0	0	0	0	0	0
Migration	0	0	0	0	0	0	0	+9	-12	+6	+6	-6	0	0	0	0	0	0
Health	0	0	0	0	0	0	0	0	0	0	0	0	+12	+6	+4	-4	+2	0
Educational	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+4
Tourism	0	0	0	0	0	0	0	0	0	0	0	0	+8	+2	+15	0	+12	+6
Landscapes	0	0	0	0	0	0	0	0	0	0	0	0	+4	+2	+9	0	+9	+1
Algebraic sum of impacts	+30	+42	-15	+27	+27	+11	+9	+69	+34	+29	+8	+15	+24	+10	+28	-4	+23	+11
Total value	+84				+47			+155					+92					

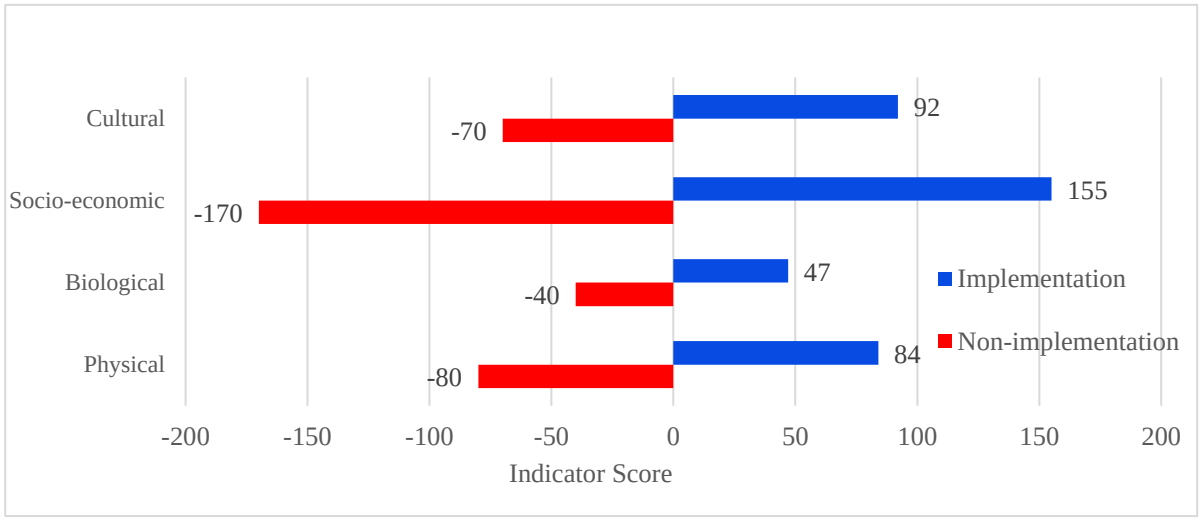


Fig. 3- Comparison of Implementation and Non-Implementation Options during the Operational Phase of the Haleh Dam Proje

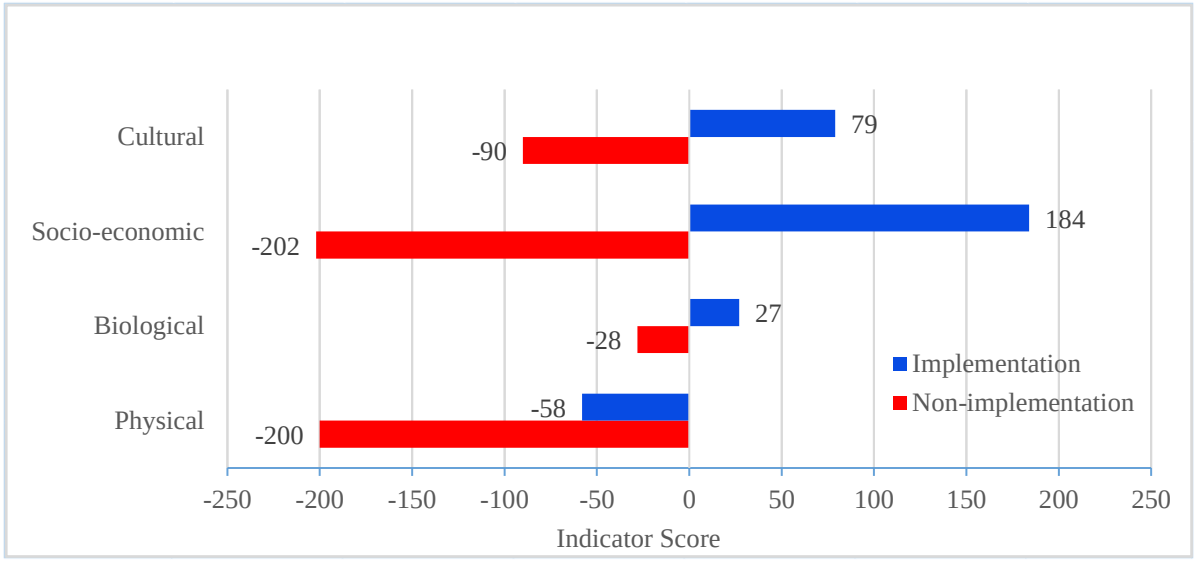


Fig. 4- Final Comparison of Implementation and Non-Implementation Options during the Construction and Operational Phases of the Haleh Dam Project

Discussion and Conclusion

This study conducted a comprehensive and quantitative environmental impact assessment (EIA) of the Haleh Dam project during both the construction and operation phases, utilizing an integrated approach based on an advanced scoring checklist. The adopted methodology enabled a multidimensional evaluation by quantitatively analyzing the project's effects across four key environmental domains: physical, biological, socio-economic, and cultural. In the construction phase, the implementation scenario recorded a cumulative negative score of –146, demonstrating a relatively lower adverse impact compared to the non-implementation scenario (–160). The most substantial negative effects were associated with the physical environment, primarily driven by excavation and embankment operations, the use of heavy machinery, and wastewater generation. However, in the operation phase, the implementation scenario resulted in a significant cumulative positive score of +378,

underscoring the long-term environmental benefits of the project. The socio-economic environment exhibited the highest positive contribution (+155), reflecting improvements in water availability, flood control, tourism development, job creation, and enhancement of community welfare. Additional positive impacts were also observed in the cultural (+92), physical (+84), and biological (+47) environments, indicating ecological recovery and improved infrastructure conditions.

The final comparative evaluation of the two scenarios implementation (+232) and non-implementation (–520) across both project phases suggests the potential environmental justification for the dam project, conditional upon the effective implementation of mitigation and monitoring measures. These findings indicate that, despite some temporary adverse effects during construction, the project has the potential to contribute to sustainable regional development if ecological and cultural limitations are properly mitigated and monitored, alongside enhanced agricultural productivity, reliable water supply for domestic, agricultural, and industrial uses, flood damage mitigation, and the strengthening of the local ecosystem. Moreover, the optimal use of the reservoir for recreational, tourism, and sport activities offers valuable socio-economic development opportunities for local communities.

The Gotvand Dam project in Iran is a clear example where significant negative environmental effects were identified after construction, particularly the salinization of the Karun River. Nevertheless, management reforms such as controlled reservoir operation, salt-layer isolation, and long-term monitoring were developed and implemented to mitigate the impacts (Sayadi et al., 2009). Similar adaptive management strategies were also proposed for the Zhoveh Dam project (Karimi et al., 2019). These lessons underline the necessity of adopting an adaptive management pathway for the Haleh Dam as well, ensuring that identified ecological risks remain under control throughout its operational lifespan.

Compared with the hybrid IDOCRIW–COCOSO approach by Eslami et al. (2021), the present study extends the weighting ranking integration by embedding adaptive monitoring indicators and cumulative effect analysis in the GIS environment. While both frameworks employ entropy-based criteria weighting to minimize subjective bias, our Haleh Dam model reveals higher criterion sensitivity under semi-arid conditions, highlighting the contextual dependency of socio-ecological priorities.

In developing regions, the integration of cumulative and cross-project effects into Environmental Impact Assessment (EIA) remains a persistent limitation. For instance, a recent study conducted around the Campo-Ma'a National Park in Cameroon (Zo'obo Engolo et al. 2024) applied the Sorensen and Rau framework to evaluate multiple development projects near a protected area. Despite moderate consideration of direct impacts ($\geq 79\%$), cumulative effects and integrated management were addressed to a limited extent ($\approx 52\%$), largely due to insufficient data and fragmented monitoring systems. The authors proposed combining matrix and network-based approaches, alongside digital platforms, to strengthen impact tracking. These findings align with the rationale of the present study, which emphasizes quantified and adaptive assessment tools as an effective means of overcoming similar data and integration challenges.

Nevertheless, to minimize the negative impacts during the construction phase, it is recommended to implement effective control measures such as frequent water spraying to reduce dust, afforestation in erosion-prone zones, use or retrofitting of modern machinery, installation of pollution-control filters, and provision of proper sanitation infrastructure (e.g., septic tanks). During the operational phase, training farmers in the judicious use of fertilizers and pesticides, along with promoting biological pest control methods, can play a crucial role in reducing ecological pressures and enhancing the resilience of the local ecosystem.

Limitations

Despite the robustness of the proposed analytical framework, several inherent limitations should be noted. First, the scoring process inevitably involves a degree of subjectivity, as it relies on expert judgment despite efforts to standardize criteria through quantitative checklists. However, this subjectivity was minimized by involving a multidisciplinary panel of 36 experts and by applying uniform weighting and inter-rater reliability calibration during the scoring process.

Second, although the Haleh Dam project has now entered its operational phase, comprehensive long-term environmental monitoring data are still being accumulated, which currently limits the empirical verification of all predicted impacts.

Third, the evaluation did not include direct participation of affected local communities, which may limit the integration of socio-cultural concerns and local knowledge. Nonetheless, a participatory extension phase has been planned during the ongoing monitoring stage to incorporate local stakeholders' feedback and traditional ecological knowledge (TEK) into adaptive management.

Finally, while cumulative effects were conceptually considered, the framework has not yet been extended to transboundary or large-scale cumulative interactions. Future research should expand this component through GIS-based regional frameworks and shared environmental databases, ensuring more comprehensive ecosystem-level accountability.

Overall, the proposed analytical framework owing to its flexibility, quantification capacity, and transparency demonstrates strong potential as a practical and reliable decision-support tool for environmental impact assessments of infrastructure projects. By providing objective numerical comparability across project alternatives, it contributes to evidence-based decision-making aligned with the principles of sustainable development. Therefore, the 'Advanced Checklist' may be viewed as a structured enhancement and modernization of existing EIA tools rather than a fundamentally new model.

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Authors' contribution

First Author: Nader Nabipour, Study design, data collection, initial drafting; revise methods/results.

Second Author: Babak Lashkar-Ara Overall supervision, final study structure, full data analysis/interpretation, final edits/submission.

Reference

1- Ansar, A., Flyvbjerg, B., Budzier, A. and Lunn, D., 2014. Should we build more large dams? The actual costs of hydropower megaproject development. *Energy Policy*, 69, pp. 43–56. doi: 10.1016/j.enpol.2013.10.069.

2- Bragagnolo, C., do Nascimento, N. and Geneletti, D., 2017. Streamlining or sidestepping? Political pressure to revise environmental licensing and EIA in Brazil. *Environmental Impact Assessment Review*, 65, pp. 86–90. doi: 10.1016/j.enpol.2013.10.069.

3- Canter, L. W. and Wood, C., 1996. *Environmental impact assessment*. 2nd ed. London: McGraw-Hill.

4- Dehnavi, R. and Kouzehgar, R., 2019. Evaluation of ICOLD Matrix for Environmental Impact Assessment of the Peyghamchay Dam. *Environmental Monitoring and Assessment*, 191(10), article 607. doi: doi:10.1007/s10661-019-7767-4.

5- Eslami, V., Ashofteh, P.-S., Golfam, P. and Loáiciga, H.A., 2021. A multi-criteria decision-making approach for managing environmental impacts of dam construction using the IDOCRIW–COCOSO method: Case of Nohob Dam, Iran. *Water Resources Management*, 35(12), pp. 4231–4246. doi: 10.1007/s11269-021-02932-1.

6- Fearnside, P. M., 2016. Environmental and social impacts of hydroelectric dams in Brazilian Amazonia: Implications for the aluminum industry. *World Development*, 77, pp. 48–65. doi: 10.1016/j.worlddev.2015.08.015.

7- Geneletti, D., 2005. Formalising expert opinion through multi-attribute value functions: an application in landscape ecology. *Journal of Environmental Management*, 76(3), pp. 255–262. doi: 10.1016/j.jenvman.2005.01.025.

8- Glasson, J., Therivel, R. and Chadwick, A., 2013. *Introduction to Environmental Impact Assessment*. 4th edn. London: Routledge.

9- Javadi, S., Mohammadi, K. and Khodadadi, A., 2007. The environmental impact assessment of Gotvand Upper Dam using the combination of two methods of ICOLD and Leopold matrix. *Environmental Sciences*, 4(3), pp. 35–48 [In Persian].

10- Karimi, S., Bouzari, S. and Saadat Foomani, M., 2019. Environmental impact assessment of Zhaveh Dam construction using checklist and ICOLD matrix methods: Case study of Zhoveh Dam. *In: Proceedings of the Conference on Environmental Science, Engineering and Technologies (CESET 2019)*, Faculty of Environment, University of Tehran, Tehran, Iran. (In Persian).

11- Khodabakhshi, M., Zahraee, B. and Malekmohammadi, B., 2011. Environmental impact assessment of dam construction using multi-criteria ELECTRE and decision matrix methods. *Environmental Sciences*, 8(2), pp. 115-128. (In Persian).

12- Leopold, L. B., 1971. *A procedure for evaluating environmental impact*. Vol. 645. Washington, DC: US Department of the Interior.

13- Lerer, L. B. and Scudder, T., 1999. Health impacts of large dams. *Environmental Impact Assessment Review*, 19(2), pp. 113–123. doi: 10.1016/S0195-9255(98)00040-9.

14- Lyu, H. M., Sun, W. J., Shen, S. L. and Arulrajah, A., 2018. Flood risk assessment in metro systems of mega-cities using a GIS-based modeling approach. *Science of the Total Environment*, 626, pp. 1012–1025. doi: 10.1016/j.scitotenv.2018.01.138.

15- Makhdoum, M., 2008. Problems arising from non-compliance with environmental considerations in water projects. in *Proceedings of the Conference on Environmental Impact Assessment of Water Resource Development Projects* . (In Persian).

16- Modak, P. and Biswas, A. K., 1999. *Conducting environmental impact assessment for developing countries*. Tokyo: UNU Press.

17- Morgan, R. K., 2012. Environmental impact assessment: The state of the art. *Impact Assessment and Project Appraisal*, 30(1), pp. 5–14. doi: 10.1080/14615517.2012.661557.

18- Mostert, E., 2003. The challenge of public participation. *Water Policy*, 5(2), pp. 179–197. doi: 10.2166/wp.2003.0014.

19- Pope, J., Bond, A., Morrison-Saunders, A. and Retief, F., 2013. Advancing the theory and practice of impact assessment: Setting the research agenda. *Environmental Impact Assessment Review*, 41, pp. 1–9. doi: 10.1016/j.eiar.2013.01.008.

20- Sadler, B. and Verheem, R., 1996. *Strategic environmental assessment: Status, challenges and future directions*. Ministry of Housing, Spatial Planning and the Environment, the Netherlands: International Study of the Effectiveness of Environmental Assessment.

21- Sánchez, L. E. and Morrison-Saunders, A., 2011. Learning about knowledge construction in environmental impact assessment follow-up. *Environmental Impact Assessment Review*, 31(3), pp. 211–218. doi: 10.1016/j.eiar.2010.12.002.

22- Sayadi, A., Khodadadi, D. A., and Partani, S., 2009. Environmental impact assessment of gotvand hydro-electric dam on the Karoon River using ICOLD technique. *International Journal of Environmental and Ecological Engineering*, 3(6), pp.118-123. doi: 10.5281/zenodo.1339949.

23- Valizadeh S. and Shekari Z., 2015. Evaluation of Iranian Leopold matrix application in the environmental impact assessment (EIA) of solid waste management options in Birjand city. *Health and Environment*, 8(2), pp. 249–262. (In Persian).

24- World Commission on Dams (WCD)., 2000. *Dams and development: A new framework for decision-making*. London: Earthscan Publications.

25- Zo'obo Engolo, G.M., Dieudonné, S., Mbog Mbog, S., Polmbaye, P. and Bitondo, B., 2024. Cumulative Impact Assessment of Development Projects Around Campo-Ma'an National Park in Cameroon. *Journal of Environmental Assessment and Management*. doi: 10.37256/epr.4220244571.

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