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RISK ASSESSMENT FOR THE HYDROPOWER PROJECTS: A STUDY FOR SCIO- TECHNICAL DIMENSIONS OF MOHMAND DAM FOR SUSTAINABILITY

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Article Info

Abstract

The Mohmand Dam Hydropower Project is an important project for Pakistan, a country that is struggling to meet its demands for water, power, and climate change. The project is aimed at generating 800 MW power, storing water, and preventing water surge, all of which are important for the development and adaptability to climate change. To ensure a better understanding of the project's environmental sustainability, the scientific investigators interviewed people, engineers, and decision-makers, and also used statistical methods to analyze the issue. Many people are quite positive about the project's benefits, such as having enough water, power, and farming factors, which are important for the development of the country. The dam may alter the natural flow of the river, impacting different species of plants and animals. To reduce the negative and enhance the positive, it is important to get involved with the people, engineers, and decision-makers to participate in the deliberation process, which may help to find possible problems and solve them for the betterment of all. In brief, the Mohmand Dam Hydropower Project is a project that may make a huge difference for Pakistan. However, it is very important to address the environment-related and social issues linked to it. In this case, the project can become a success story in the country, promoting economic development, climate change adaptation, and sustainability.

Keywords:

Risk Assessment; Dam Analysis; Technical; Social; Sustainability.

1. Introduction

The Mohmand Dam Hydropower project in Mohmand district of Khyber Pakhtunkhwa is a key project by Pakistan promoting sustainable development. The Water and Power Development Authority (WAPDA) designed this multipurpose project to be one of the main interventions to solve serious issues in water management, energy security, flood control, and to enhance socioeconomic development. It is proposed that the dam may be a solution to the long-term water shortage, energy crisis and regular flood issues affecting Pakistan, and that this project could trigger a paradigm shift in the hydrological and energy environment of the region. The ability to store 2 million acre-feet (MAF) of water and produce 800 megawatts (MW) of clean and renewable electricity is the embodiment of the holistic approach to using and sustaining resources expressed in the Mohmand Dam. The dam's ability to store two MAF of water beyond energy is an important intervention for improving water resource management. The irrigation systems fed by Reducing water supplies that supply around 19 percent of Pakistan's GDP and over 38 percent of its labor force are heavily reliant on Pakistan's agro-economic sector. The Mohmand Dam is going to be a game changer - it will store water in a smart way and release it when it's needed most, which means fewer water deprivation and a big increase in farming, especially in the areas downstream [1]. Plus, it will help limit the number of floods that happen, which is a huge deal because these floods affect large demographic group and destroy their livelihoods [2]. By controlling the water flow, the dam will make a big performance gap in people's lives.

Pakistan is suffering from various problems and this project is of prime importance towards solving them. Pakistan is in dire water crisis, it is considered one of the countries in the world which suffers from water scarcity [3]. This leads to lack of water in various houses in Pakistan and is indeed a major problem. Similarly, we witness flood after flood inundating houses, farmlands and roads, which demonstrates the need for a proper strategy to overcome such issues [4]. We require quick and substantial solutions to these problems. Furthermore, there is also a shortage of energy in the country which has inhibited industrial progress and also made living difficult for people at home. Mohmand Dam is an integral project which can effectively tackle such major problems. The Mohmand Dam is a key project that can help solve these big challenges and really help the country move forward. It's not just about one problem, it's about many issues that are all connected, and this dam can be a crucial part of the solution. Pakistan is a water scarce country where per capita water availability has fallen from 5,260 cubic meters in 1951 to less than 1,000 cubic meters in the last years, which has pushed Pakistan in the category of water-scarce countries. While the Mohmand Dam has a lot of benefits, there are also a lot of issues that need to be addressed before the project can be successful [5]. These also include potential environmental and social impacts such as displacement of local people, changes in aquatic ecosystems and sedimentation problems [5]. The impact of the project was evaluated through Environmental and Social Impact Assessment (ESIA) in order to identify the challenges and mitigate these challenges so that positive consequences surpass the negative impact.

Many water reservoirs in countries like Pakistan are prone to sedimentation. For this, the design of the dam implements sediment management measures adopting sluicing and flushing that preserve the reservoir storage capacity under long-term operation. The dam will also help reduce Pakistan's reliance on ground water, at unsustainable levels, resulting in aquifer depletion and poor water quality. The Mohmand Dam will help create a surface water resource that can be tapped if ground water reserves are depleted in the future. The dams are usually expected to offer an improved irrigation capacity that will boost agricultural productivity, increase crop yields and reduce the risk of food insecurity in dry and semi-arid regions [6]. Flooding is among the most devastating of natural disasters in Pakistan, destroying lives, livelihoods and infrastructure [7]. Floods have been a big problem in our country over the last ten years. Many people have lost their homes, crops have been ruined, and a lot of money has been lost because of these floods. It's predicted that the new dam will mean that land and infrastructure will be damaged a lot less. So the money will not be wasted in having to rebuild roads, houses etc. so it could be spent better in

assisting the victims after a flood. [8]. That way they are concentrating on rebuilding and helping those who are hurt instead of on cleaning up the debris.

Therefore, the projects such as Mohmand Dam provide us a hope, as Pakistan is confronting two major problems of shortage of water as well as energy [9]. This project must be developed and implemented with the highest degree of care and accuracy to yield the optimum benefits without much negative impacts on environment and population [10]. The project if designed and implemented properly can be a boon for the whole region and can be a role model for the multipurpose projects [11]. Feel the business money they are making and their house money would not be taken from them nor would they be removed. [12]. In times of abundant rainfall, the dam stores it, preventing the overflow downstream of communities becoming a hazard. When we see how important a dam is for water and energy resources, it is evident that dams will provide us with a future where we are able to sustain and remain secure [13]. The Mohmand Dam Hydropower project is one perfect example of how complex and potentially fruitful massive infrastructure projects can be. The primary problems here concern a sustainable and resilient future. This study tries to offer some lessons for other projects around the world by investigating the environmental, social and technical issues that affect the project, and the utilization of adaptive management strategies in order to minimize the long-term damage to the environment is indispensable.

2. Literature Review

Effective hydropower schemes in different parts of the world are a good source of information about environmental and social impacts management and viable development targets[14].As an example, the Three Gorges Dam in China, the largest hydropower globally, implemented the need of comprehensive environmental impact assessments (EIAs) and mitigation measures [15]. Although the project had the ability of generating a lot of energy it was criticized due to displacement of more than one million people; along with the disruption to ecological integrity that are inclusive of the loss of habitat and reduction of water quality [16] . Nonetheless, some of these effects have been reduced by the adoption of resettlement programs, fish conservation methods, and sediment management procedures [17]. The same applies to Itaipu Dam on the Brazil-Paraguay border, which is commonly described as the example of international cooperation and sustainable development of hydropower [18]. Itaipu has not only created a significant amount of renewable energy, but also provided the programs of biodiversity protection, communities support, and eco-tourism enhancement [19]. These international case studies indicate the need to balance the economic well-being and the environment and the social environment along with livelihood impacts of dams to provide lessons to future hydropower projects [20].

The experience of Pakistan with the implementation of large-scale hydropower plants like the Tarbell dam and the Mangla dam will be very useful when it comes to developing the Mohmand dam. Tarbell Dam is a mega earth filled dam of a world that has helped Pakistan in managing water and energy since 1976 when it was completed. Nevertheless, it has had its complications including, sedimentation which has decreased its storage capacity over the years, eviction of the local population, some of whom did not manage to rebuild their livelihoods properly because of the lack of proper policies of resettlement. On the same note, the Mangla Dam, although effective in the delivery of water to irrigate and power electricity, has suffered problems of sedimentation and social problems of displacement. The two projects, despite the struggles, have greatly helped in nation building in Pakistan, and this proves that hydropower has great potential in curbing water and energy crisis [21]. Examples of Tarbell and Mangla, especially in managing the sediment load, involvement of the communities, and settlement plans are of great importance to the modification of the Mohmand Dam project. Addressing them beforehand prevents the affair of past mistakes and results in the increased sustainability and social acceptability of the Mohmand Dam.

Although there have been vast researches conducted on the hydropower projects, there are still a lot of unanswered questions on the long-term effects of the projects on the ecological system and effectiveness

of the adaptive management suggestions [22]. Most studies about the environment impacts of dam constructions emphasize on the short-term impacts of the environment like death of living organisms, alteration of water quality among other aspects, but there is little information regarding the overall impact of dam construction activities on the environment. An example to illustrate this lack of research is the effect of modified river flows on aquatic diversity that has been in effect in the past decades or how such effects have been intensified by climate change [23]. Moreover, although adaptive management measures, including environmental flow releases and fish passage structures, are commonly advocated, their success in sustaining an ecological balance in the long run, is rarely recorded. The best way of filling these gaps is through longitudinal research benchmarking ecological changes over a period of time and analyzing the effectiveness of mitigation actions [24]. This kind of study is essential to create more sustainable hydropower plants that will only have minimal impact on the environment but will make the most out of that impact. The use of advanced technologies is a gap as well as the management of sediments whereas hydropower technology has improved a great deal. Real-time monitoring systems and predictive analytics are just two of the areas of dam operations that have become more and more popular but still have not given the full extension to efficiency and safety due to the scarcity of research on long-term effectiveness[25].

3. Materials and Methods

3.1 Study Area

The construction of dam's structures is usually advised in the mountainous regions due to natural conditions and feasibility to build the water structures and storage reservoirs. Mohmand Dam is a multi-purpose concrete-faced rock-filled dam (Fig.1) located on the Swat River approximately 37 km north of Peshawar in Mohmand District, Khyber Pakhtunkhwa (KPK), Pakistan. Over 40 million inhabitants of the KPK province of Pakistan live in the mountainous region facing scarcity of water for domestic consumption, means of livelihood, and water for irrigation to grow food and cash crops. Therefore, the rivers originating from the mountain/hilly areas play a key role in fulfilling the requirements of the people. To meet this demand, the Government of Pakistan conceived the Mohmand Dam Project after 1963. Realizing the serious water scarcity for both the livelihood of the inhabitants and the irrigation of agricultural land, the Government of Pakistan initiated various projects for the construction of dams. These projects are expected to contribute towards making the best use of the run-of-the-river flows, which otherwise go wasted to the sea. Hence, the concept of the Mohmand dam project is to generate hydroelectric power in the east and irrigational water in the west of the country.

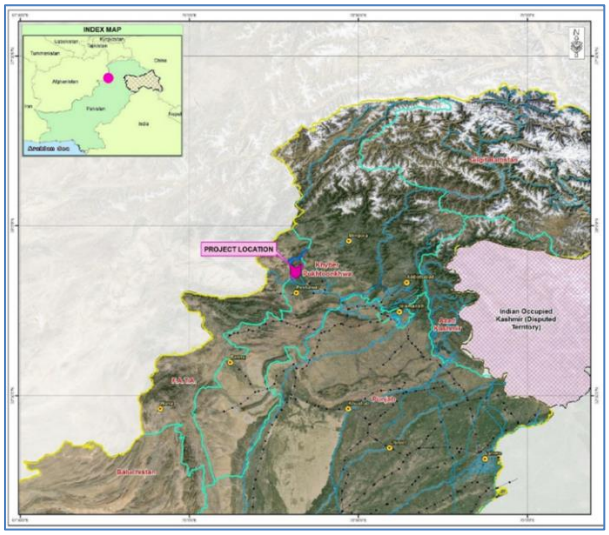

Figure 1. Study Area-Project Location

3.2 Methodology

The sufficient fundamentals are provided in the following methodology to accomplish such a project. The methodology flow chart (Fig.2) presented here shows the complete methodology from the literature review stage to the evaluation stage of the research project. After Literature review, finalize assessment methodology for the research. The research questionnaire is designed through Likert scale, consisting of sections conceived through literature study.

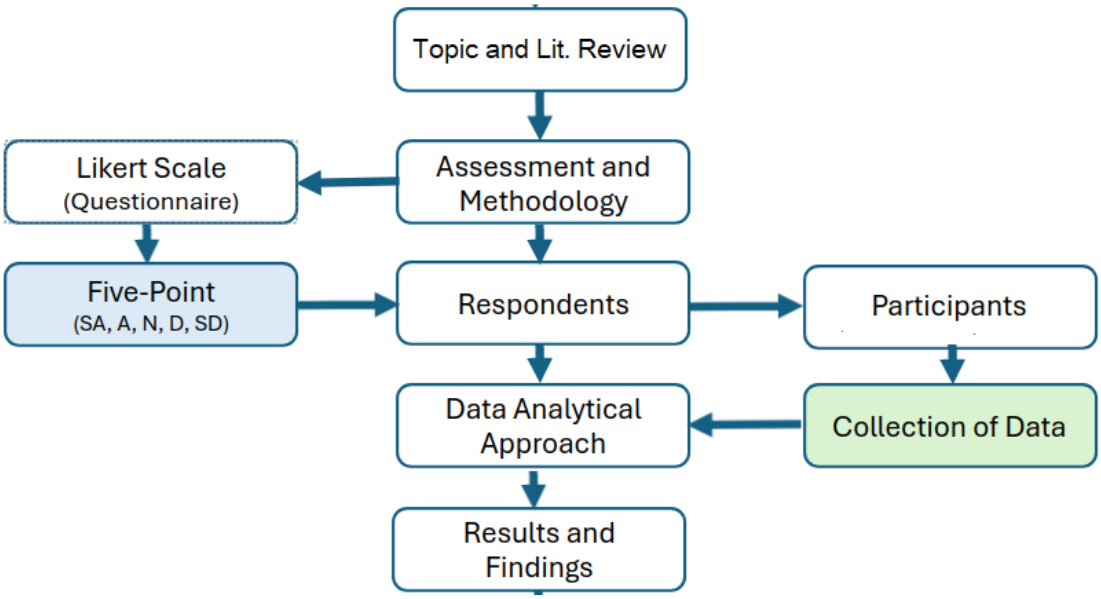

Figure 2. Methodology Flow Chart

3.3. Questionnaire Development and Validation

The questionnaire comprises four sections: (1) respondent profile, (2) environmental outcomes, (3) social and community impact and (4) quality and performance standards. A pilot study was conducted to confirm that the entire survey and feasible timing to solve. The intended audience were technical personals (included consulting engineers and infrastructure construction firms involved in hydropower development, civil engineering), and regional public stake holders. Participants were also encouraged to forward the questionnaire on to other colleagues/persons possessing the relevant knowledge and expertise.

3.4. Instrument Design: Questionnaire Construction

Not only does the literature review identify key risk variables in hydropower projects (examples: operational safety, environmental safety, and construction planning) and highlight the use of expert surveys to assess such risks, it also features the construction of a questionnaire developed for the purpose of quantifying risk variables. Used a five-point Likert scale to assess both the severity of risk variables and the effectiveness of countermeasures, as a seven-point scale proved confusing. Hydropower projects are commonly ranked in terms of risk level, and the literature shows that ranking is often directly proportional to the expected magnitude of associated losses. The method is derived by mean value calculation, ranked risk factors are from questionnaire which the formal method of designed and constructed. The categorical variables such as sex, work should be given value. All Likert scales should convert to numeric value. (Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Completely Agree

= 5) in order to analyze them quantitatively. After the cleaning processes are completed each question of the questionnaire will then become a single variable in software and each individual participant will be a row so the data can be managed and thus hopefully some useful findings from the data.

3.5. Data Collection Procedures

Getting good information from a questionnaire depends on how well it's designed. So, to create a good one, several surveys about risk assessment in hydropower projects were looked at to come up with questions. These questions were then put together into a first version of a seven-page questionnaire. To see if the questions were clear and if the way responses were recorded was good, a small test survey was done with three experts on risk. After getting their feedback, the questionnaire was made better, and a final version of the Core-Questions Form was created. This process helped make sure the questionnaire is reliable and will give useful information. Different modes of questionnaire administration were applied: paper-and-pencil surveys and online surveys via Forms. In light of the positive perceptions regarding the efficiency of online surveys, this modern mode was selected for the majority of the data collection in the risk assessment task. The gathered data were downloaded from google forms to an excel file and subsequently transferred into software for analysis.

4. Results and Analysis

4.1 Respondents Profile

Questionnaires were distributed amount to major entities, Technical Personnel and Local Residents (general public) of the dam area. From the received responses about 53% of the responses are from technical personals which are more useful in this case study and 47% local resident which can explain ecological effects and effect on living being as shown in figure no 3. Considering the important of technical opinion, in this draft only technical opinion has been analyzed to elaborate the technical perspective of the dam works.

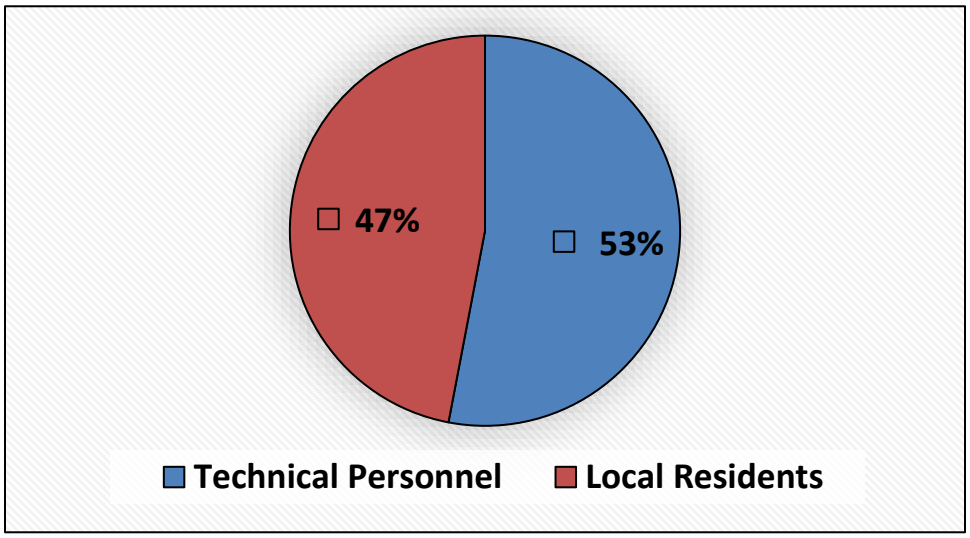

Figure 3. Graphical Distribution of Respondents

The results indicate that response was sustainable and efficient with reference to technical and general public responses. The higher the percentage of responses was received from technical personals and public responses (people and stakeholders of the areas) as shown in Fig.3.

4.2 Environmental Outcome- Technical Opinion

This table no 1 show that technical peoples feel that dams cause notable harm to ecosystem as this some were ranked as the most critical. The dam has negatively impacted local wildlife and biodiversity, The dam has harmed local river ecosystems and the dam has contributed to deforestation in the surrounding areas. These three facts were observed similar to the worldwide established opinion. This is inline with the technical people's opinion that dams besides there need are necessity environmentally disturbing natural ecological system.

Table 1. Environmental Outcomes- Technical Personnel Opinion

#	Questions	Mean	Rank
7	The dam has negatively impacted local wildlife and biodiversity.	2.67	1
3	The dam has harmed local river ecosystems.	2.6	2
9	The dam has contributed to deforestation in the surrounding areas.	2.27	3
8	The dam has reduced the risk of waterborne diseases in the region.	2.13	4
4	The dam helps communities adapt to climate change (e.g., droughts).	2.08	5
6	Water quality (for drinking/irrigation) has improved post-dam.	1.92	6
1	The dam has improved water availability for households and agriculture.	1.79	7
5	Sediment accumulation in the reservoir is a major problem.	1.71	8
2	Flood-related damage has reduced significantly since the dam was built.	1.7	9
10	The dam has improved groundwater recharge in the region.	1.58	10

4.3 Social and Community Impact- Technical Opinion

Hydro based projects impact local social structures. This assessment examines potential social and community impacts having the crucial aspects like the dam has improved healthcare facilities in the region, the dam has disrupted traditional community practices, the dam has caused social conflicts within the community, the dam has increased educational opportunities for local children and the dam has improved transportation infrastructure in the region. Potential indicators for assessing social risk, social equity, and social acceptance in future hydroelectric projects include measurement plans, relevant features for indicator articulation, and anticipated data sources. Dams are helpful and beneficial but some feel it cause disruption to tradition practices and increase social conflicts that shown in table no 2.

Table 2. Social and Community Impact- Technical Personnel Opinion

#	Questions	Mean	Rank
6	The dam has improved healthcare facilities in the region.	3.69	1
3	The dam has disrupted traditional community practices.	3.64	2
8	The dam has caused social conflicts within the community.	3.64	2
7	The dam has increased educational opportunities for local children.	3.6	3
9	The dam has improved transportation infrastructure in the region.	3.6	3
10	The dam has increased the overall quality of life in the community.	3.58	4
2	Displaced families received fair compensation and support.	3.38	5
5	The dam has improved access to electricity in my area.	3.31	6
4	Local residents were consulted during the dam's planning phase.	3.24	7
1	The dam has created more jobs for local residents.	1.62	8

4.4 Technical Performance - Technical Opinion

Areas like maintenance, safety, and flood control are viewed less positively, indicating concerns about the dam's long-term efficiency. the table suggests that respondents have mid-level confidence in the dam's technical output, like the dam's construction was completed within the planned timeline, sediment management (e.g., flushing) works effectively and advanced technologies are used to monitor dam performance. with construction completion rated the highest that shown in table no 3.

Table 3. Technical Performance- Technical Personnel Opinion

#	Questions	Mean	Rank
6	The dam's construction was completed within the planned timeline.	2.29	1
2	Sediment management (e.g., flushing) works effectively.	1.92	2
5	Advanced technologies are used to monitor dam performance.	1.87	3
9	The dam's design minimizes environmental harm.	1.83	4
3	The dam meets the region's energy demands.	1.77	5
8	The dam's energy generation is consistent and reliable.	1.71	6
4	Flood control systems operate reliably during heavy rains.	1.62	7
10	The dam's technical performance meets international standards.	1.62	7
1	The dam's design ensures long-term safety and efficiency.	1.52	8
7	The dam's maintenance practices are effective and timely.	1.46	9

4.5 Quality and Performance Standards- Technical Opinion

Establishing well-defined quality and performance standards for design, construction, operation, and maintenance of hydroelectric projects is crucial for minimizing risks and ensuring long-term viability. An appropriate framework specifies desired quality parameters and the corresponding degree of compliance necessary to mitigate exposure to quality-related hazards. In tandem with a description of the selected framework, the associated monitoring requirements should be indicated to facilitate compliance assessment. Adherence to internationally recognized quality norms, rules, and regulations is paramount to avoid the imposition of undesirable consequences by investors and key stakeholders. The table shows that rising living costs are the main concern, while fiscal benefits like business growth and agriculture are viewed favorably but less strongly that shown in table no 4.

Table 4. Quality and Performance Standards- Technical Personnel Opinion

#	Questions	Mean	Rank
3	Living costs have risen since the dam's construction.	1.94	1
1	The dam has boosted local businesses and investments.	1.87	2
2	Agricultural productivity has increased due to the dam.	1.62	3
4	The dam provides sustainable economic opportunities.	1.52	4

5. Conclusions

The topic which the study centered around was the Mohmand Dam Hydropower project. The primary objective of the study was to get a big picture view of the risk involved in the dam project. The main issues focused on were the impact the project would have on the environment, society and technology. Another objective of the study was to develop an understanding about how stakeholders viewed the project. The researchers interviewed different groups of people. Based on the statistics obtained the researchers concluded that most of the people felt that the project would be beneficial and was a good idea. All the people interviewed felt that it would bring water, lessen flooding, generate energy and produce crops for farmers. Most people expressed confidence in the dam's engineering, functionality and international standards. Such reactions are completely natural due to long existing problem of water scarcity, flooding and lack of electricity supply. It's all good news, in terms of technical and financial aspect, however social and environmental problems should not be underestimated. This highlights the need for an integrated risk assessment that takes in technical, social and environmental factors.

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