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A Comprehensive Risk Evaluation: A Case Study of Super Madi Hydropower Project

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Abstract

Hydropower projects are a great source of clean energy, but they come with many risks that can affect their success. Risk is anything that can delay a project, raise costs, or lower quality. It is important to correct and manage risks early, before the project starts. The study aims to uncover conceivable risks inherent in hydropower projects. The fundamental goal of this study is to determine the likelihood of risk occurrences in hydropower projects, from conceptualization to operationalization. A quantitative research approach was employed, utilizing structured questionnaires distributed to key stakeholders involved in the Super Madi Hydroelectric Project (SMHP), including clients, contractors, and consultants. A total of 48 questionnaires were distributed, with 47 responses received. The questionnaire comprised 34 questions across seven major risk categories, and risk prioritization was conducted using the Relative Importance Index (RII). The reliability of the data was confirmed with Cronbach's alpha ($\alpha = 0.786$), ensuring internal consistency. The results identified natural calamities as the most significant physical risk, followed by geological and groundwater subsurface conditions. Additionally, labor and material availability, inflation, regulatory changes, and environmental impacts were identified as critical risk factors. This kind of information can help future hydropower projects plan better, avoid common problems, and stay on track. Managing these risks well can lead to safer, more efficient, and more sustainable energy projects.

Keywords: Hydropower risks, Relative importance index, Risk assessment, Super Madi Hydroelectric Project,

1. Introduction

Hydropower plays a major role in addressing the global demand of renewable energy in the region where there are sufficient natural water resources. By utilizing the potential renewable water resources, hydropower is contributing the sustainable development by mitigating climate change. However, hydropower developments are inherently complex and subject to extensive risks, including technical, financial, environmental, legal and policy issues, socio-political and technological challenges (Adhikari et al., 2023; Shaktawat & Vadhera, 2021). Effective management of these risks is essential to ensure project success, maintain economic viability, and achieve the intended environmental, societal benefits and sustainable economic development (Chen et al., 2022). Hydropower projects face significant risks, including cost overruns, schedule delays, and environmental and social challenges, which require thorough identification, prioritization of potential threats and analysis for sustainable development by mitigating measures (Barber, 2005; Gurung, 2020; Shaktawat & Vadhera, 2021). Thus effective risk management is critical to mitigate these challenges and achieve project objectives (Al-Bahar & Crandall, 1990).

Infrastructure projects are highly susceptible to risks due to their complexity and the uncertainties (Kalinina et al., 2016). Effective risk identification and management are crucial to ensure these projects meet their objectives despite the diverse challenges they face (Ribas et al., 2019). The goal is not to eliminate all risks but to focus on critical threats that could significantly impact project outcomes. This approach ensures accountability, minimizes disputes, and enhances the stability and success of projects. Effective risk management depends on interconnected factors, including work processes, spotting and early risk assessment (Thamhain, 2013).

Hydropower project construction is known for its lengthy timelines, large scale, high costs, involvement of numerous participants, and complex construction conditions. It is deeply interconnected with economic, social, and ecological factors. As a result, the construction management approach and risk management strategies for such projects have garnered significant attention from various sectors (Li et al., 2023). In hydropower projects, major key risks include environmental and natural issues, site geology (Kucukali, 2011; Roy et al., 2014; Tripathi & Shrestha, 2017), hydrology, construction, political (Nepal et al., 2021), financial constraints, and socio-economic environmental challenges (Morimoto, 2013). Effective risk management requires a multidimensional approach that integrates technical expertise, stakeholder engagement, and policy frameworks to identify, mitigate, or avoid potential issues for project success (Roy & Roy, 2020). If these risk factors are not managed in a timely manner, they can cause schedule and cost overruns, resulting in delayed power availability at higher costs and, in extreme cases, project failure (Shaktawat & Vadhera, 2021; Shrestha & Kayastha, 2021). Risks in construction projects can be broadly categorized into technical, operational, financial, political, and environmental risks (Maseko, 2017). Each category presents unique challenges that must be addressed to ensure project success. Technical risks, for example, stem from design flaws, inadequate site investigations, and changes in project specifications (Musa & Obaju, 2016). Operational risks may include labor shortages, equipment failures, and logistical disruptions. Financial risks, such as cost escalations and funding shortfalls, require careful budget planning and contingency measures. Political risks, including policy changes and regulatory uncertainties, demand active engagement with government authorities and advocacy for stable legal frameworks. Environmental risks, such as habitat destruction and watercourse modifications, necessitate comprehensive environmental impact assessments and sustainable design practices (Shaktawat & Vadhera, 2021).

In recent years, advancements in risk assessment methodologies have enhanced the ability to manage risks in hydropower projects. Techniques such as Monte Carlo simulations (Mubin et al., 2019; Oliveira et al., 2021; Zaroni et al., 2019), influence diagrams, and fuzzy set concepts(Ji et al., 2015; Wang et al., 2023) have been employed to model uncertainties and prioritize risk mitigation measures.

In Nepal, development of hydropower has been identified as a critical component of the national energy strategy. Despite many efforts, the pace of hydropower development has been slow, constrained by challenges including bureaucratic inefficiencies, limited technical expertise, and a lack of coordination among stakeholders (Chaurasiya et al., 2013). Additionally, the country's geophysical structure makes hydropower projects prone to environmental, health related risks and natural hazards including landslides, floods, and glacial lake outburst floods particularly during the construction and operational phases of hydropower projects (Nie et al., 2023). Addressing these challenges requires a holistic approach, integrating technical, financial, and environmental considerations (Zayed & Chang, 2002). Despite these challenges, Nepal's hydropower sector offers immense potential for growth and development. In Nepal, hydropower projects (HPPs) face significant challenges due to the lack of comprehensive studies on risk assessment and management. There is an absence of through, site specific evaluations. Many previous studies provide a broad overview of risk evaluation of different HPPs but not about SMHP. In this study the research question is as follows: What are the primary risks in the hydropower project ? Which risks have the greatest impact on the successful operation and development of the project ?

The aim of this study is to evaluate the risks associated with the SMHP. This investigation encompasses the following specific objectives:

1. To determine the primary risks, present in hydropower projects and their relative ranking.
2. To determine the risks that have the most significant impact on the hydropower projects.

This study benefits professionals in hydropower projects by providing insights to government officials for policy and planning, helping developers and consultants prioritize and manage risks, and enabling project managers to implement timely mitigation strategies to prevent delays and cost overruns.

2. Study Area

According to the Super Madi Hydropower Limited (2025) the SMHP lies between latitudes 28°19′02″N to 28°21′39″N and longitudes 84°04′45″E to 84°08′34″E in Madi rural municipality, Kaski District, Gandaki Province, Nepal. The Kathmandu-Pokhara - Bijaypur Khola - Sabi - Tangtin Village route leads to it. The headworks is roughly 8 km from Tangtin Village, which is in the middle of the project area. Major parts of the headworks are located on the left bank of the river (Figure 1 and 2). It uses water from Madi Khola and has a 44 MW installed capacity as a run-of-river scheme. The project has a catchment area of 278.136 km^2, with a design discharge of 18 m^3/s. The project includes a 5.9-kilometer headrace tunnel, a circular surge tank (37-meter height, 9-meter diameter), and steel penstocks. The semi-surface powerhouse contains three Francis turbines. The project generates 242.65 GWh of net yearly energy (37.756 GWh dry, 205.894 GWh wet) and delivers electricity to the NEA substation in Lekhnath via a 132 KV substation. This infrastructure highlights the project's role in harnessing hydropower for energy production in the region.

SMHP is geologically situated within the Higher Himalayan Crystalline Zone, lying just above the active Main Central Thrust (MCT), a major tectonic boundary in the Himalayas (Figure 1 and 2). SMHP area is located within medium to high grade metamorphic rocks. This zone primarily includes kyanite and gneiss, schist, quartzite, and augen and banded gneiss (Gautam, 2012; Nepal, 2025). The main lithology across the project area is characterized by banded and micaceous gneiss, which varies slightly fractured to highly fractured and is often intercalated with schist and quartzite. Rock mass conditions range from fair to good, with thick to massive foliation and varying degrees of fracturing. However, the area is not without geological risks. Significant folding and shearing are present along surface slopes, particularly on the right hillside, where numerous old landslides indicate active slope instability due to shear failure (Gautam, 2012). This presents potential geological and geotechnical risks to SMHP. Slope movement can also impact long-term operational safety. MCT, a major tectonic boundary, indicates a seismically active zone. Earthquakes in such areas can trigger ground shaking, landslides, or induce fault reactivation; all of which pose serious risks to hydropower infrastructure.

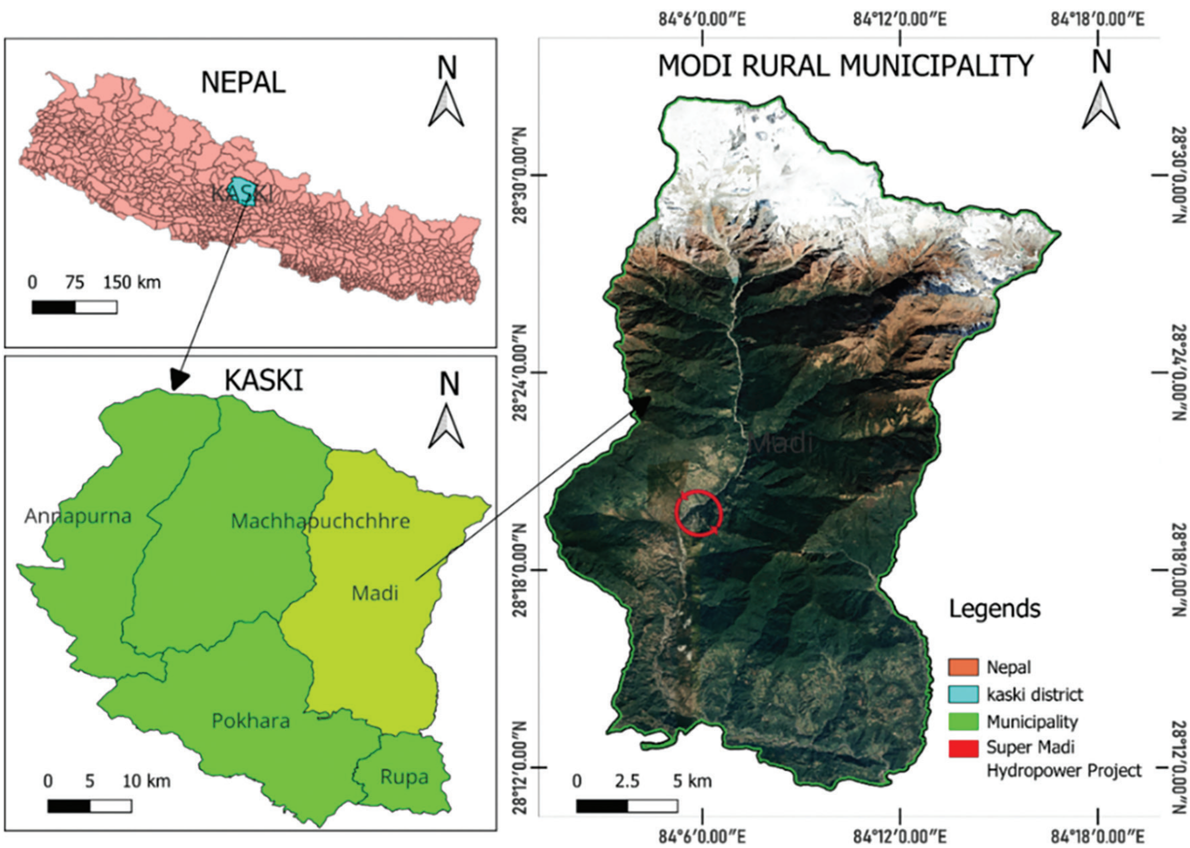

Figure: 1: Study Area Map showing SMHP in the Madi River Basin.

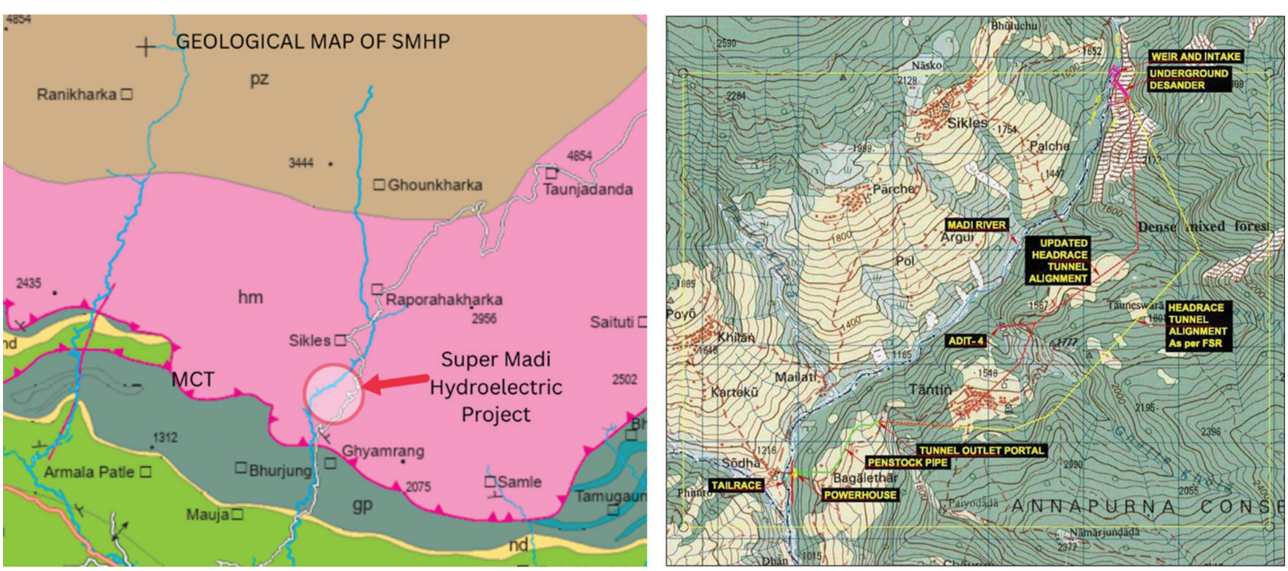

Figure 2: Layout of SMHP in the Madi River Basin (44 MW) (Source: Super Madi Hydropower Project Report) (Nepal, 2025)

3. Materials and Methods

This study adopts a mixed-method approach, integrating both quantitative and qualitative data collection and analysis techniques (Saunders et al., 2009). Hydropower specific risks were identified from the review of literature. The methodology comprised comprehensive review of literature, followed by questionnaire survey interview conducted for the study. The questionnaire was formulated in five point Likert scale of 1 denoting very small, 2 denoting small, 3 for normal, 4 large and 5 for very large has been used for probability level of the risk occurrence and degree of impact or the level of loss if risk occurs.

3.1. Study Population

The study participants include clients, consultants, and contractors from the SMHP, selected through purposive sampling based on availability. This questionnaire survey interview included 48 respondents from three different groups. 14 client personnel from SMHL, 9 consultant personnel from Sanima Hydro and additionally, 24 respondents were selected from the 237 contractor personnel of Fewa Construction. This selection ensured a representative sample for the study.

3.2. Sample Size Calculation

Sample size for the finite population is calculated using equation 1 (Adhikari, 2021)

Table 1: Sample Size Calculation

Parameters	Client	Consultant	Contractor
Z- Score (Z)	1.96	1.96	1.96
Population proportion (P)	0.5	0.5	0.5
Population Size(N)	14	9	25
Margin of error (e)	0.05	0.05	0.05
Sample Size(n)	13.508	8.794	23.473
Adopt	14	9	24

$$n = \frac{(Z)^2.p(1-p)/e^2}{1+\frac{Z^2.p(1-p)}{e^2.N}} \qquad 1$$

Where-,

n=size of the sample, e=margin of error (percentage in decimal form), p=population proportion, N=Population size, Z= Z-score (1.96 for 95% degree of confidence)

The sample size is calculated using 95% degree of confidence, 0.5 population proportion and 5% error (Table 1).

3.3. Data Collection

A site visit was conducted during February and March 2023 as part of the case study for the risk assessment of the SMHP. The primary goal of the visit was to collect essential survey data and available reports. The SMHP began test production on March 2023 (Republica, 2023). The risk assessment was done after the construction phase, allowing for real observations of the risks experienced during and after construction.

Key Informant Interviews (KIIs) were conducted to identify strategies for managing risks in hydropower projects. The selection of key informants was based on available information, and participants were chosen from organizations (Consultant, Client and Contractor) actively involved in the hydropower development. A structured questionnaire was developed to assess the perceptions of clients, contractors, and consultant about the risks encountered during the construction of the project. The questionnaire was divided into two sections section A and section B: Section A focused on general questions to identify the respondent's role, gender, and years of experience in the construction industry. Section B contained 34 questions addressing the causes and consequences of risks, divided into seven categories: Construction risks, Physical risks, Performance risks, Contractual and legal risks, Financial and economic risks, Sociopolitical risks and Environmental risks. The questionnaire was designed based on insights from previous studies and a thorough literature review (Deviprasadh, 2007), including research work on risk assessment and management in construction projects, forming the foundation for the study's questionnaire design. Responses collected from various groups were analyzed using SPSS software. Secondary data were collected from various sources, including journal articles, textbooks, online resources, websites, and social media platforms. Key sources included previous research studies, pertinent Acts and Regulations, published and unpublished literature, reports, journals, and records maintained by the SMHP office.

3.4. Data analysis

The study analyzed field survey data using Excel and SPSS, ensuring accuracy and consistency. It combined qualitative insights from stakeholders with statistical methods like Cronbach's Alpha, Kendall's coefficient, and the Relative Importance Index to evaluate data comprehensively. Cronbach's alpha is a crucial measure in the evaluation of assessments and questionnaires, ensuring reliability, validity, internal consistency and accuracy in data interpretation (Bhattarai et al., 2025; Cronbach, 1951; Tavakol & Dennick, 2011; Vaske et al., 2017). It measures the correlation between items to determine how well they collectively represent a specific construct. In this study, SPSS software was used to calculate Cronbach's alpha, evaluating the internal consistency and reliability of the questionnaire items.

Kendall's Coefficient of Concordance (W) is a non-parametric statistic used to measure agreement among multiple rankings of N objects by K judges. It is particularly useful for identifying consensus in rankings when no objective order exists. The process involves ranking objects, summing the ranks for each object, and calculating the statistic using:

$$w = \frac{12s}{(N^3 - N)K^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where s is the sum of squared deviations of rank sums, K is the number of judges, and N is the number of objects. The W value ranges from 0 (no agreement) to 1 (complete agreement), indicating the degree of consensus.

Various researchers (Agrawal, 2010; Gunduz et al., 2013; Kometa et al., 1994; Sambasivan & Soon, 2007; Sudirman & Hardjomuljadi, 2011) had used RII method to assess the relative significance of different causes of delays. This study also used the same method of RII. The RII determines the significance of factors, such as contributors to construction delays, by aggregating participant ratings. It is calculated as:

$$\mathrm{RII} = \frac{\sum W}{AXN} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where W is the rating given by respondents (ranging from 1 to 5), A is the highest possible rating (5 in this case), and N is the total number of participants. This method provides a comparative ranking of factors based on their perceived importance.

4. Results and Discussion

The data collected from respondents were analyzed using statistical tools, providing insights into various risk factors and their impacts. The questionnaire consisted of two sections with structured closed-ended questions designed to meet the study's objectives.

4.1. Response Rate of the Survey:

A total of 48 questionnaires were distributed to respondents from the SMHP, with 47 responses received, achieving an overall response rate of 97.92%. The breakdown of the response rates was as follows: 100% for consultants, 96% for contractor personnel, and 100% for client personnel.

4.2. Analysis of Surveyed Data

4.2.1 Cronbach's Coefficient Alpha "α"

Cronbach's alpha (α) was employed to evaluate the reliability of the five-point scale used in the survey (Bhattarai et al., 2025; Vaske et al., 2017). While a value of 0.7 is generally accepted as the minimum threshold, values as low as 0.6 can be acceptable for exploratory studies (Joseph F. Hair Jr., 2018). The consistency of each question category was assessed by combining responses from all three stakeholder groups. The reliability analysis was conducted using SPSS software, which generated the Cronbach's alpha reliability statistics for the questionnaire (Table 2). The α values for test as performed in SPSS on data collected for probability level of the risk occurrence for each group of questions exceeded 0.7 (table 2), indicating a high level of internal consistency within each group. The overall α value of 0.786 confirms that the questionnaire maintained reliability across all groups, despite variations in the number of questions and consistency levels among them.

The Cronbach's alpha (α) values for test as performed in SPSS for the level of loss if risk occurs for all questionnaire groups exceeded 0.7, indicating strong internal consistency within each group. The overall α value of 0.770 demonstrates that the questionnaire was reliable as a whole, even with variations in the number of questions and consistency levels across different groups.

Table 2: Result of Cronbach's Alpha Reliability Test

Reliability Statistics for	**Probability level of the risk occurrence**			**The level of loss if risk occurs**		
Group	**Cronbach's Alpha (αi)**	**N of Items (Ni)**	**αi * Ni**	**Cronbach's Alpha (αi)**	**N of Items (Ni)**	**αi * Ni**
Group A: Construction Risk	0.821	8	6.568	0.93	8	7.44
Group B: Physical Risk	0.805	3	2.415	0.713	3	2.139
Group C: Performance Risk	0.768	10	7.68	0.732	10	7.32
Group D: Contractual and Legal Risk	0.77	3	2.31	0.709	3	2.127
Group E: Financial and Economic Risk	0.79	3	2.37	0.714	3	2.142
Group F: Socio Political Risk	0.79	5	3.95	0.713	5	3.656
Group G: Environmental Risk	0.712	2	1.424	0.726	2	1.452
	Total	34	26.72	Total	34	26.82
	Reliability		0.786	Reliability		0.77

Kendall's Coefficient of Concordance (W) assesses the agreement among multiple sets of rankings for a given number of items. In this study, W for the probability of risk occurrence is 0.486, surpassing the critical value of 0.44 at a 0.05 significance level (k=3, N=34), indicating significant agreement among three groups for 34 questions. Similarly, W for the level of loss due to risk is 0.680, confirming concordance among the groups for the same questions. RII was employed to analyze questionnaire data, ranking risk factors based on their likelihood and impact, considering both individual and overall group responses.

4.2.2 Construction Risk

The likelihood of construction related risks was evaluated using RII, incorporating responses from clients, contractors, and consultants to assess their perspectives (Figure 3). The RII results indicate that variables had relatively low scores, suggesting a low likelihood of occurrence in construction projects (Genc, 2023). Consultants ranked labor availability, material availability, and plant/equipment availability as the top construction risks, while clients focused on plant/equipment availability, labor availability, and material availability, and contractors highlighted late drawings and instructions, defective designs, and design changes as their key concerns (Figure 3). Similarly, ranking of construction risk factors on the basis of impact / loss, consultants identified labor availability, material availability, and third party delays as the top construction risks, while clients prioritized labor availability and equally ranked material availability and plant/equipment availability, and contractors focused on late drawings and instructions, followed by design changes and delayed site access. The findings on construction risks suggest a direct influence on cost and time overruns, leading to deviations from the planned budget and scheduled project duration (Nepal et al., 2021).

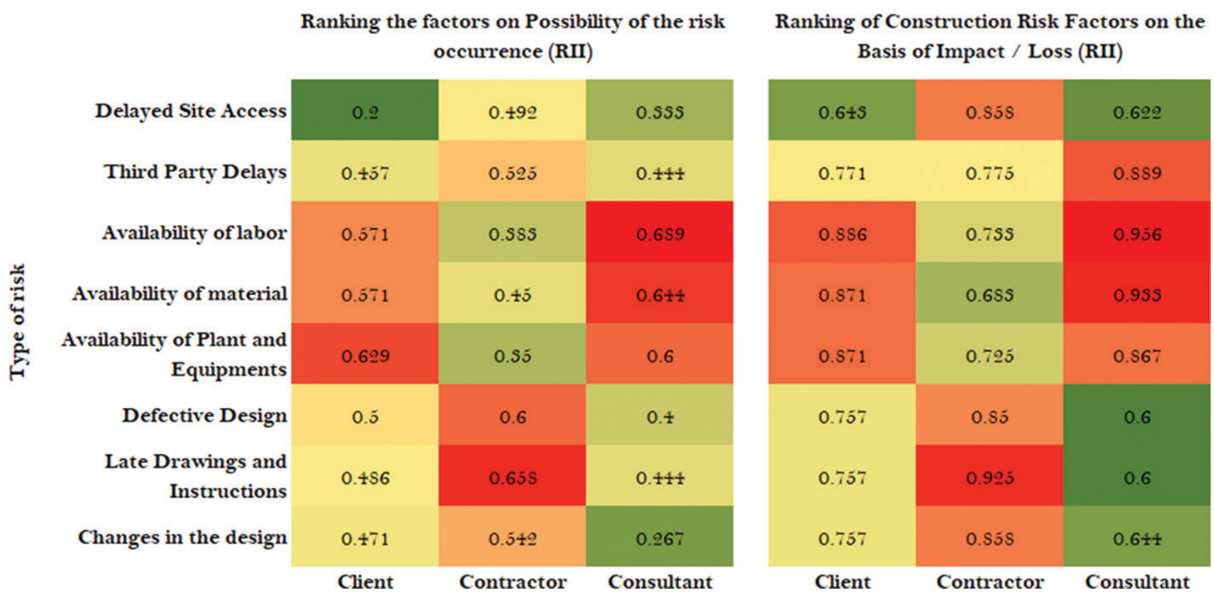

Figure 3: Heatmap visualization for Ranking of Construction Risk Factors

4.2.3 Physical Risks

The likelihood of physical risks was assessed by calculating the RII based on the responses from clients, contractors, and consultants (Figure 4). When considering possibility of the risk occurrence, consultants identified natural calamities as the highest physical risk, followed by geology and groundwater subsurface conditions. Contractors prioritized geology subsurface conditions as the most critical, with natural calamities and groundwater conditions also significant. Clients similarly ranked geology/subsurface conditions as the top risk, along with natural calamities and groundwater issues.

Similarly considering degree of impact or level of loss if the risk occurs natural calamities, geology, and groundwater conditions were deemed equally critical by clients and consultants, while contractors ranked geology subsurface conditions highest, followed by groundwater and natural calamities. Climate change can increase the risk of natural calamities such as glacier lake outburst floods and landslides which is a primary risk for hydropower development (Ray et al., 2018). Natural hazards are a bigger threat to development in Bhutan which is located in fragile Himalayan region (Dorji et al., 2024).

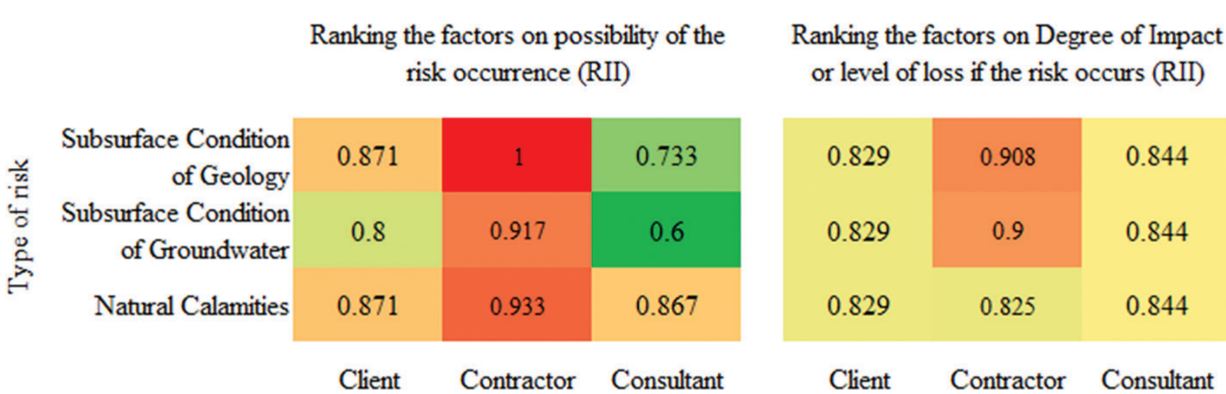

Figure 4: Heatmap visualization for Ranking of Physical Risk Factors

4.2.4 Performance Risks

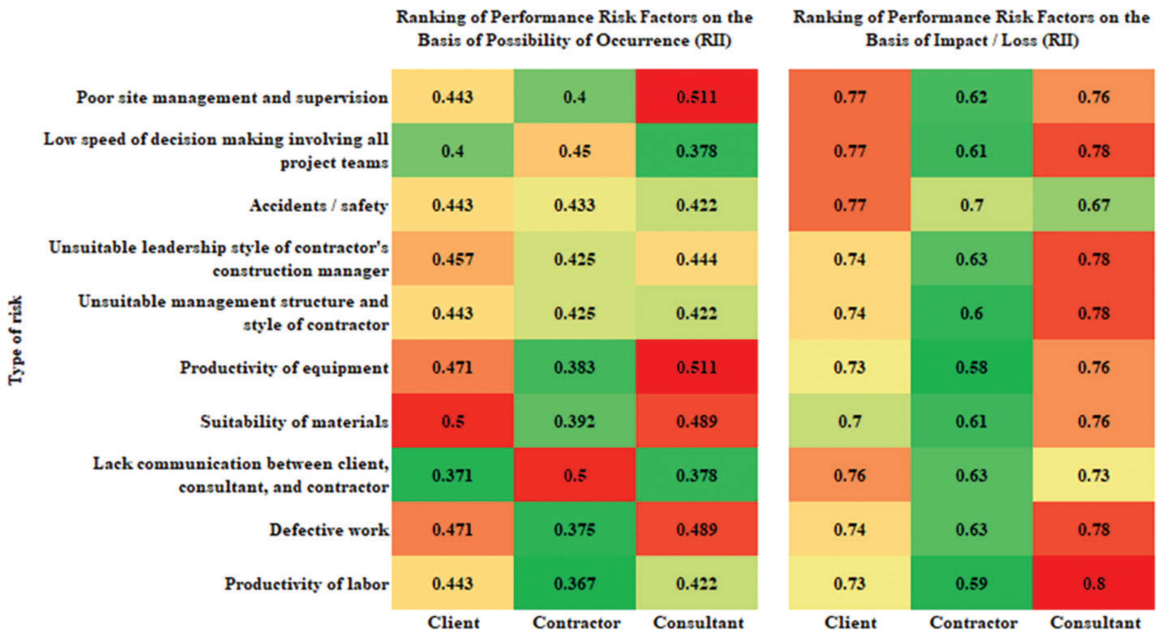

Figure 5: Heatmap visualization for Ranking of Performance Risk Factors

Considering possibility of performance risk occurrence consultants identified poor site management and supervision as the top performance risk, followed by productivity of equipment and suitability of materials (Figure 5). Clients ranked suitability of materials as the top performance risk, followed by defective work and productivity of equipment. Contractors identified lack of communication among stakeholders as the highest performance risk, with slow decision-making (RII: 0.45) and accidents/safety issues ranked second and third, respectively. Similarly, considering basic impact and loss, consultants identified labor productivity as the top risk, followed by unsuitable leadership style and management structure, while clients ranked poor site management, low decision-making speed, and safety issues as the highest risks, and contractors highlighted accidents/safety, unsuitable leadership, and communication gaps as their key concerns (Figure 5).

4.2.5 Contractual and Legal Risks

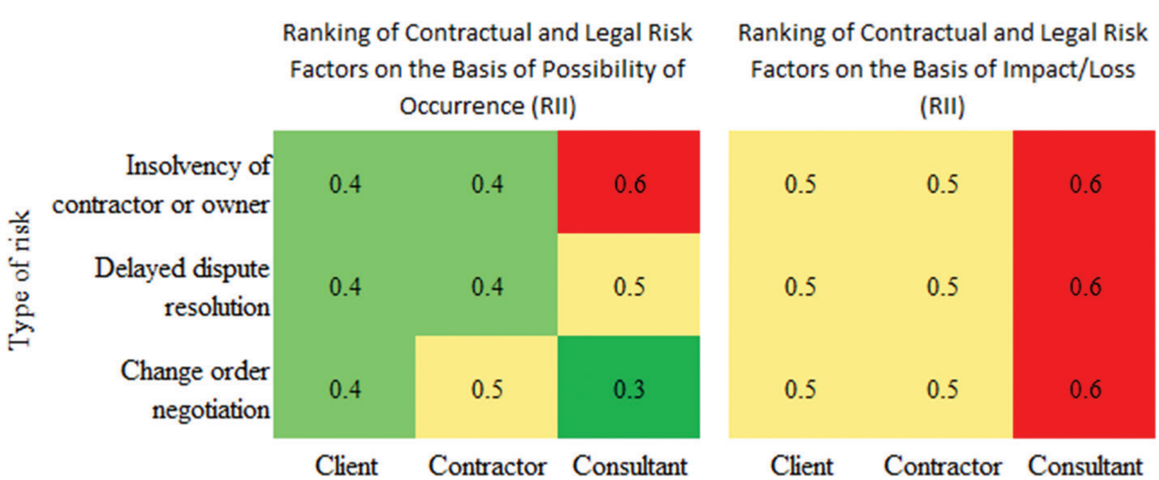

Figure 6: Heatmap of Ranking of Contractual and Legal Risk Factors

The analysis of contractual and legal risks revealed (Figure 6) that consultants identified contractor/owner insolvency as the top risk, followed by delayed dispute resolution and change order negotiation, while clients ranked delayed dispute resolution as the highest risk, followed by change order negotiation and contractor/owner insolvency, and contractors prioritized change order negotiation, delayed dispute resolution, and contractor/owner insolvency based on the basis of possibility of occurrence. On the Basis of Impact/Loss all three stakeholders agreed that delayed change order negotiation poses the greatest risk, followed by delayed dispute resolution and contractor/owner insolvency as the second and third most significant risks, respectively.

4.2.6 Financial and Economic Risks

The likelihood of financial and economic risks was assessed using the Relative Importance Index (RII) based on responses from clients, contractors, and consultants. All three groups collectively ranked interest rates as the highest risk, inflation the second, and the impact of monetary policies (national and international) the third (Figure 7). Individually, clients and consultants assigned equal RII to inflation, interest rates, and monetary policy impacts, while contractors ranked inflation as the highest risk, interest rates the second, and monetary policy impacts the third based on the potential degree of impact or loss.

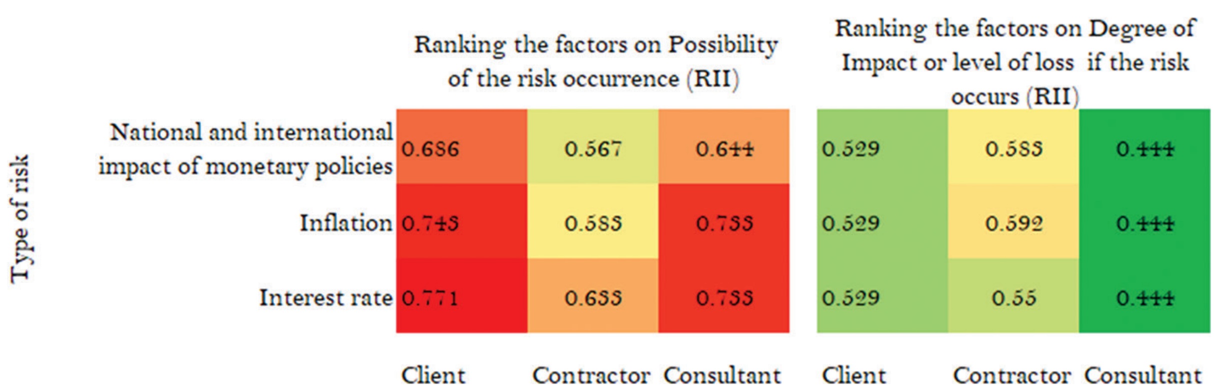

Figure 7: Heatmap visualization of Ranking of Financial and Economic Risk Factors

4.2.7 Socio-Political Risks

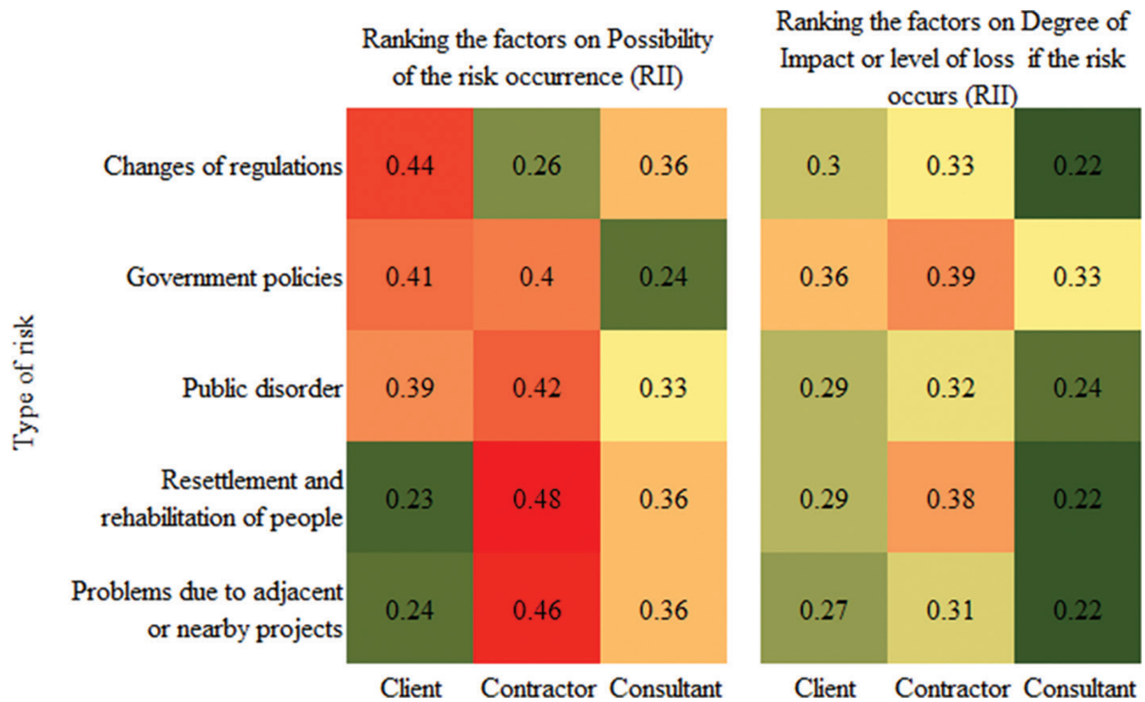

Figure 8: Heatmap visulization of Ranking of Scio-Political Risk Factors

The analysis (Figure 8) of socio-political risks based on the likelihood of occurrence revealed that consultants rated changes in regulations, resettlement and rehabilitation, and issues from nearby projects equally. In contrast, clients identified changes in regulations, government policies, and public disorder as the most significant risks, while contractors prioritized resettlement and rehabilitation, issues from nearby projects, and public disorder. When assessed based on impact or loss, all three stakeholder groups agreed that government policies were the highest risk. However, clients ranked changes in regulations and resettlement as the second and the third most significant risks, contractors placed resettlement second and regulations the third, and consultants prioritized public disorder the second and resettlement the third.

4.2.8 Environmental Risks

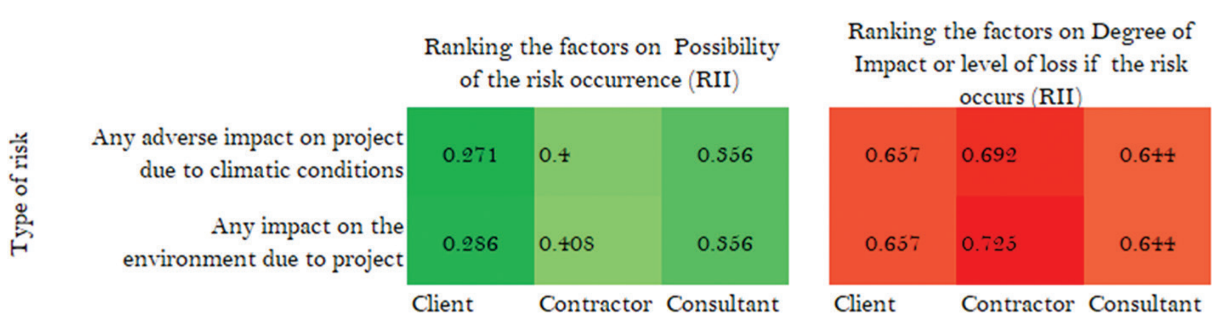

Figure 9: Visualization of Ranking of Environmental Risk Factors

The analysis of environmental risks revealed that all stakeholders (consultants, contractors, and clients) unanimously ranked project related environmental impacts as the top risk, followed by the impact of climatic conditions as the second most significant risk (Figure 9).

4.2.9 Overall Ranking of the Project Risk

The study assessed risks using RII and identified key risk factors based on their likelihood and impact. The likelihood of each potential risk identified in the study was evaluated using the RII, based on the combined responses of clients, contractors, and consultants (Figure 10 and 11). It is clear that the RII value of subsurface geological conditions, natural calamities and sub-surface conditions of groundwater is greater than 0.80. As per Genc 2023, this is considered very high level risk (Genc, 2023). This is highly relevant in Nepal due to terrain challenges, remote access, high precipitation zone, highly earthquake-prone region, and unforeseen geological conditions. The 2015 Gorkha earthquake also highlights the vulnerability of hydropower infrastructure in Nepal. Also during monsoon season, the steep slopes of the Madi River catchment area and other similar Hydroelectric project areas of Nepal are prone to landslides due to their fragile geology.

4.2.10 Measures to Minimize the Risks

After identifying the major risks affecting the project, key informant experts involved in the Super Madi Hydropower Project were consulted for practical solutions. Drawing from their hands on experience and in-depth understanding of the project environment, they shared several targeted recommendations. These suggestions are grounded in the challenges actually encountered during project implementation and are summarized below:

- Detailed and precise field investigations including hydrological, geological, and sediment studies are crucial before finalizing the design and construction. Inadequate initial surveys often lead to repeated design changes, which in turn cause costly delays. Investing in accurate site assessments from the start can help avoid these issues.
- Subsurface conditions in the Himalayan region are highly unpredictable. The team recommended that all underground components (e.g., tunnels, surge shafts) should be based on verified geological geotechnical tests. Doing this early saves both time and money by preventing design changes and structural modifications later on.
- Given the project's exposure to floods, landslides, and other natural disasters, hydropower developers need to adopt project-specific insurance plans. These could include parametric insurance models that trigger payouts based on predefined environmental indicators, allowing for quicker recovery.
- Several respondents highlighted the need for more consistent and transparent policies especially in areas related to land acquisition, resettlement, and community engagement. Ambiguities in these areas often lead to delays and disputes during implementation.
- Pre-planning to address local concerns was identified as a key success factor. Effective community engagement through dialogue, and addressing demands early can reduce the risk of public obstruction during construction.
- When preparing contracts, developers should ensure that terms and conditions are unambiguous and fair. This prevents future conflicts or misinterpretation by contractors, which can lead to legal or operational setbacks.
- Finally, stakeholders called for more proactive government involvement, particularly in easing access to construction resources like fuel, equipment, and transmission infrastructure. Adjustments in tariffs and regulatory processes were also mentioned as important enablers for smoother project execution.

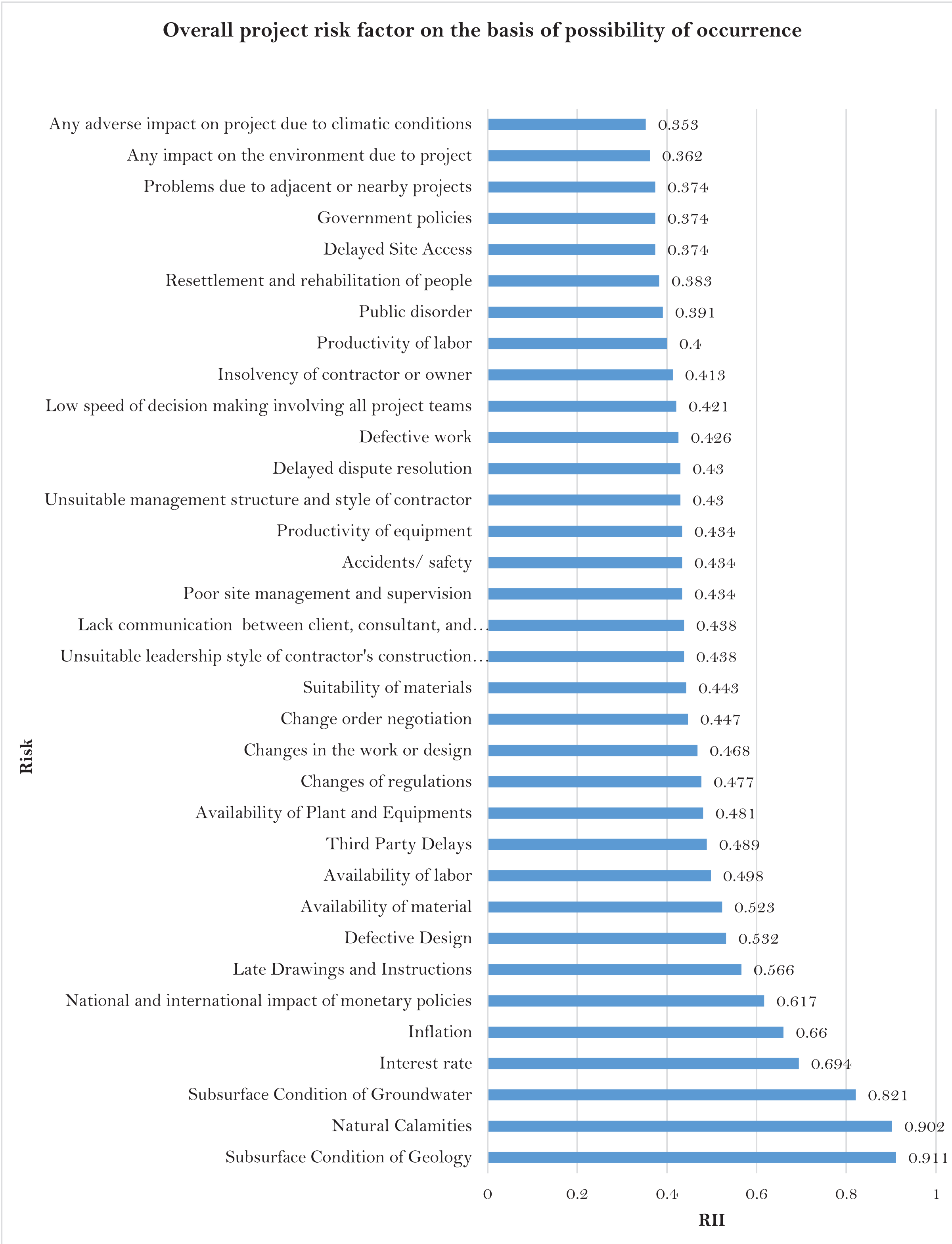

Figure 10: Ranking of overall project risk factor on the basis of possibility of occurrence

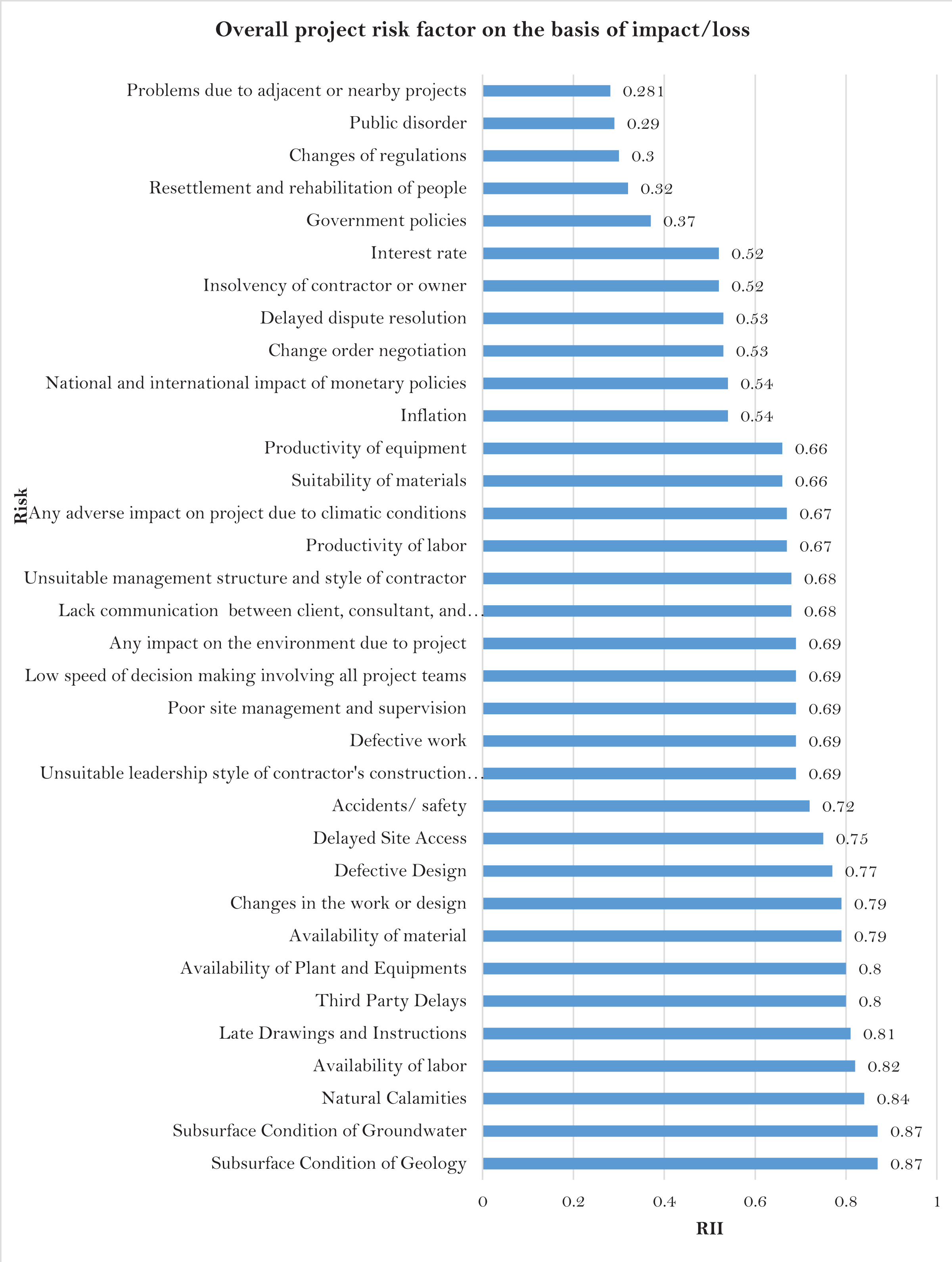

Figure 11: Ranking of overall project risk factor on the basis of impact/loss

4.2.11 Risks Faced by the Project

The major challenges encountered by the SMHP included natural calamities, subsurface geological issues, and labor shortages. Natural calamities, such as the flood that occurred on June 15 2021 in the Madi basin, caused significant damage to headwork structures and the powerhouse, resulting in financial losses of approximately NPR 1 billion and an 8 month work disruption (Lamsal, 2024). Geotechnical challenges necessitated design changes, including shifting the surge shaft location due to weak subsurface geology and addressing potential rock fall hazards. Labor shortages, exacerbated by the COVID-19 pandemic, further delayed construction, although effective contractor management mitigated some impacts.

5. Conclusion

This study highlights that stakeholders (clients, consultants, and contractors) hold differing perspectives on the likelihood and impact of various risks associated with hydropower projects. By analyzing 34 risk factors across seven major categories, using RII, and incorporating insights from Key Informant Interviews (KII), the study identified key risks factors.

Among the 34 risks factors, subsurface geological conditions, natural calamities and sub-surface conditions of groundwater emerged as the most significant in terms of both likelihood and impact. Natural calamities, in particular, were consistently identified as critical across both construction and physical risk categories. Labor and material availability were deemed high risk factors for performance, while 'change order negotiation' posed significant challenges within contractual and legal risks. Inflation and interest rates were ranked as the most critical financial and economic risks, with regulatory changes and public disorder leading socio-political risks. Lastly, adverse environmental impacts of projects were recognized as low in likelihood but high in potential impact.

In conclusion, this research provides insights for developers, funding institutions, contractors, and consultants in preparing effective risk response plans for sustainable hydropower project development in Nepal. The findings underscore the critical importance of addressing natural calamities, subsurface geological conditions, and sub-surface conditions of groundwater identified as the primary risks in such projects. Effective management of these factors is essential for the smooth execution and long-term sustainability of hydropower projects in Nepal.

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