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Tunnel Risk Assessment Using Analytic Hierarchy Process (AHP): Case Study of Two Tunnels of Nepal

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Abstract

A significant amount of financing and funds are invested annually into major construction and infrastructure projects. Tunnelling is one of the fundamental infrastructures of a developed nation, despite the hazards involved. Particularly among the greatest challenges for project managers is identifying and analysing risks, which can lead to reduced productivity and failure to finish the project. Therefore, tools that can identify and evaluate risks should be designed. Through the use of the AHP method, it was determined that the most significant risk area was Geotechnical (26.04%), which is fair given that tunnel projects necessitate a great deal of attention to this issue due to factors including the tunnel squeezing, rock mass collapse, water inrush, portal collapse etc. The second primary risk dimension was Natural Hazards (15.44%) including landslide, fire, earthquake, etc. The proper disaster relief mechanism must be included in the design in order to respond to disasters. Third primary risk dimension was Safety-Related Risks (15.13%), and attention is required for worker's safety as tunnelling consists of confined space, harmful gases from blasting, hit by heavy equipment, etc. The research presented a comprehensive tool for assessing tunnel risks in Nepal, which is a vital resource for determining the extent of risk linked to tunnel initiatives in Nepal.

Keywords

Tunnel Projects, Risk Areas, Risk Assessment, AHP, Multi- criteria decision- making process

1. Introduction

Globally, tunnel construction has increased. Most tunnel construction projects have been completed without incident. There is, however, an inherent risk associated with tunnel construction, as it entails the largely unknown subsurface. There have been a number of incidents in various tunnelling projects that have resulted in delays, cost overruns, and, in a few instances, injuries and fatalities [1]. Consequently, there is a growing need to evaluate and manage the hazards associated with tunnel construction.

Nepal resides in the center of the Himalayan arc. Around 83% of the country's total land area consists of highlands and mountains. Due to the steep topography, tunnelling and underground works play an important role in the development of infrastructure and mineral resources [2]. The country's primary economic resources are water resources (hydropower, irrigation, and potable water), agriculture, tourism, and agrotourism-based industries at present [3]. Thus, for full utilization of country's resources, development of essential infrastructures such as hydropower systems, irrigation systems, transportation networks, potable water systems, and storage facilities, etc. is necessary. The development of all these infrastructures will necessitate the utilization of subterranean space, such as tunnels and caverns. The development of numerous medium-scale hydropower projects has resulted in a significant increase in tunnelling activities in this country over the past few years. The majority of tunnelling projects constructed in the past were plagued by severe stability issues that caused completion delays and cost overruns.

Typically, these risks are resolved through risk assessment and risk mitigation techniques. However, the absence of appropriate risk assessment methods in our country has caused many tunnelling projects to incur cost and time overruns. Due to the ever-increasing complexity of tunnelling projects and the ever-increasing pressure for cost reduction and construction duration reduction, the implementation of risk assessment and management in the tunnel construction industry in Nepal is a necessity in the present day.

2. Literature Review

2.1 Risk Management Approach

Risk is a measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability and consequences [4]. Brief exposition to the consequences of uncertainty that will have an effect on the goals of the project constitutes the risk [5]. Risk is inherent in all aspects of engineering projects, regardless of their nature, and its identification and management are essential components of project management. Risk is an inherent aspect of all engineering applications. Tunnel construction, a common field of practice for mining and civil engineers, is also susceptible to dangers originating from various sources. Due to the duration and expense overruns associated with tunnel construction projects, tunnelling has always been regarded as a high-risk endeavor.

2.1.1 Identification of Risk

Identifying risks is the initial stage of the risk management procedure. It entails the identification of hazards and its causes and a description of risk and uncertainty responsibilities [6]. Risk identification is performed by conducting a methodical search for an answer to the question, "What incidents could reasonably occur that would obstruct the completion of the essential components of the tunnel construction?"

2.1.2 Assessment of Risk

Uncertainty and risk assessment determines the relevance of uncertainty and risk causes to the project's objectives. It is an answer to the query, "What is the likelihood which this risk will actually happen?" How severe will the project's consequences be if a risk continues to actually happen? Determining the likelihood of occurring and the severity of hazards constitutes risk assessment.

2.1.3 Mitigation of Risk

The mitigation strategy minimizes or eradicates the effect of uncertainty and risk on the implementation of the project. The question concerns what must be done and who is responsible for eliminating or minimizing the impact of risk and uncertainty. Strategies that can be used for mitigation include the following: control, avoidance, or transfer [6].

2.2 Risk Analysis Techniques

Evaluation of risk may be qualitative or quantitative. Using a predetermined ranking scale, a qualitative risk analysis ranks the identified project risks in order of importance. Risks will be rated based on their probability or propensity of occurring and their potential impact on the goals of the project. Probability or likelihood is ordinarily measured on an index that ranges from 0 to 1. The impact scale is defined by the organization (for example, a scale from one to five, with five representing the biggest influence on the project's goals like time frame, budget, or quality). A qualitative risk analysis also involves a proper source-based or effect-based classification of risks [5]. Some of the qualitative risk analysis techniques are Preliminary Hazard Analysis (PHA), Checklist, Bow-Tie Analysis, Security Vulnerability Analysis (SVA), HAZOP, etc.

Similarly, a quantitative risk analysis involves assigning a number or quantifiable ranking to the most significant risks so as to construct a statistical assessment of the project. A quantitative analysis determines the potential outputs for a project and evaluates the likelihood of achieving specific project objectives. It offers an analytical technique to decisionmaking in the presence of uncertainty and also it establishes expenses, timeline, and plan objectives that are real and attainable. Some of the quantitative risk analysis techniques are Failure Mode & Effects Analysis (FMEA), Event Tree Analysis (ETA), Fault Tree Analysis (FTA), Analytic Hierarchy process (AHP), Fuzzy Logic, etc. Among these techniques, AHP method is used in this paper. Because of the intricacy of tunnel infrastructure, the risk analysis procedure must not be overly complex in order to manage a large number of hazards. On the contrary, the AHP method is able to combine the assessment findings for different plans and time periods, and it can be easily implemented when experts with diverse backgrounds participate [7]. (Dikmen & Birgonul, 2006[8]; John et al., 2014[9]; Li & Zou, 2011[10]; Zayed et al., 2008[6]) are some of the papers which has also applied AHP for risk assessment. AHP method is simplest and widely used methods to handle complex risk factors.

2.3 Risk Factors Identification

(Zayed et al., 2008) [6] identified two primary areas of risk that impact roadway projects: company (macro) and project (micro) levels; evaluating their effect on risk; and introducing a risk model (R) that facilitates this evaluation process and ranks these projects. Four Chinese case studies (projects A, B, C, and D) were chosen for implementing and assessing the results of the designed model (R). Using the AHP, the R index model is developed. In the macro level (company) areas, political risk has the greatest average weight, whereas at the micro level (project), technology risks carry the greatest weight on average.

Similarly, (Wang et al., 2016) [7] proposed a major infrastructure risk assessment framework (MIRAF) developed on an improved Analytic Hierarchy Process (AHP) risk assessment approach, and extends it to the proposed cross-sea route connecting Guangdong Province and Hainan Island. The tunnel and bridge options for the cross-sea route have been compared in terms of the hazards related with their respective durations for the project. Findings show that the risk associated with the bridge project is greater than the risk associated with the tunnel project, and that this risk will continue to rise as time goes on. During the execution of the tunnel scheme, a number of major risks, such as harm to the economic interests of local fishermen, harm to the natural environments of rare and threatened species, the economic downturn, and storm surges have been identified.

(Kuo & Lu, 2013) [11] mentioned in their study utilization of fuzzy multiple criteria decision making (FMCDM) to comprehensively assess the risk associated with a metropolitan construction project. This method is capable of producing quantitative and comparable risk evaluation findings that can be applied effectively for comparing and selecting alternate schemes. In this paper, risks related to design, construction, safety, natural hazards and social and financial conditions are identified and assessed.

(Pennington & Richards, 2011) [12] examines the behavior of the soil during construction. Studies of cases are used to demonstrate the impact which geotechnical risks may impact on tunnel construction projects, as well as the methods used to reduce these hazards are explained.

(Lin et al., 2020) [13] put forward the normal cloud model by incorporating randomness and fuzziness into risk evaluation in order to produce results that are more precise. The research demonstrates how the enhanced cloud model provides an improved logical and rational assessment of risks by employing fuzzy random principle, that establishes an innovative approach for tunnel construction risk assessment.

(Hyun et al., 2015) [14] discusses the possible danger of adverse events arising when tunnelling using shield tunnel boring machine (TBM) in addition to a risk assessment that can carefully evaluate overall risk values. From the past cases and communication with industry experts, possible risks and usual tunnel shield TBM situations were examined. Related hazards from unfavorable incidences have been categorized into four categories: cutter-related failure, machinery obstruction, mucking issues that impede moving excavated materials, and section flaws.

Some papers divide these risk dimensions into engineering and non-engineering risks, while others divide them into internal and external risks. Numerous studies have been conducted on the appraisal of engineering and internal risks in tunnel projects, but external or non-engineering risks, particularly those associated with social and public demand, have received less attention.

From an exhaustive review of the aforementioned literature, a concept was developed, which assisted in identifying various tunnel construction risk factors as shown in Table 1. In order to further validate the questionnaire, three tunnel experts were interviewed and some tunnel risk factors prevalent in Nepal were incorporated. The final risk areas identified is shown in Figure 7.

Table 1: List of relevant literature reviewed for risk factors

Type of Project	Risk Dimension	Authors
Chinese Highway Project	A. Macro level risk 1. Financial 2. Political 3. Cultural 4. Market B. Micro level risk 1. Technology 2. Contracts and legal issues 3. Resources 4. Design 5. Quality 6. Construction 7. Others	Zayed et al., 2008
Major Infrastructure Project	1. Environmental risks 2. Project implementation risks 3. Decision makers' behavior risks	Wang et al., 2016
Metropolitan Construction	1. Engineering design 2. Construction management 3. Construction safety-related 4. Natural hazards 5. Social and economic	Kuo & Lu, 2013
Tunnel	1. Geotechnical risk	Pennington & Richards, 2011
Tunnel	1. Tunnel squeezing	Panthi & Nilsen, 2007
Subway Tunnel	1. Fire Risk	Gao et al., 2014
Tunnel	1. Rock mass quality 2. Monitoring measurement 3. Safety management of constructors 4. Equipment operation and management	Lin et al., 2020
Shield TBM Tunnel	1. Geological factors 2. Design factors 3. Construction management factors	Hyun et al., 2015
Rail Project	1. Financial and economic risk 2. Contractual and legal risk 3. Subcontractors related risk 4. Operational risk 5. Safety and social risk 6. Design risk 7. Force majeure risk 8. Physical risk 9. Delay risk	Ghosh & Jintanapakanont, 2004

2.4 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a multiple-criteria decision-making tool which have been applied in almost every application based on people's capacity to make significant choices [15]. This method is particularly suited for evaluating projects where qualitative variables predominated. Nonetheless, it can be described as a multi-criteria decisionmaking process that can incorporate both quantitative and qualitative variables in evaluating possibilities as a whole. AHP hierarchy can be described as shown in Figure 1.

To determine weights, the AHP relies on the inherent capacity of humans to use knowledge and expertise to calculate respective values through paired comparisons involving both intangible and tangible concerns. Therefore, the AHP goes from basic pair-wise comparisons to the hierarchy's priorities, that is, it offers a method to numerically think about that one factor can be more crucial than another in determining the efficiency of the system [16]. Experts were reminded to construct pair-wise judgements as per scale shown in Figure 2.

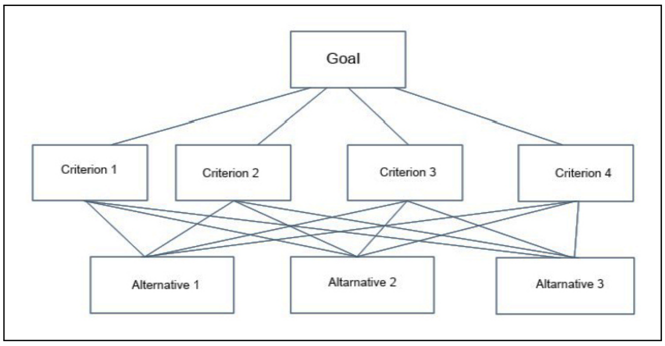

Figure 1: Hierarchy of AHP (Source:(Ali & Wali, 2020)

Scale	Numerical Rating	Reciprocal
Extremely Preferred	9	1/9
Very strong to extremely	8	1/8
Very strongly preferred	7	1/7
Strongly to very strongly	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	¼
Moderately preferred	3	1/3
Equally to moderately	2	½
Equally preferred	1	1

Figure 2: Fundamental Scale of AHP (Source:(Ali & Wali, 2020) [17]

To be able to ascertain the uniformity of the weightage evaluation, the consistency ratio (CR) must be calculated as part of the process of decision-making. The Consistency ratio of a matrix is computed using the formula CR= CI/RI, where CI is the Consistency index and RI is the Random consistency index. The CI is computed by:

$$CI = \frac{\lambda max - n}{n-1}$$

Where, lambda max is the greatest principal eigenvalue of an n * n positive inverse pair-wise comparison matrix. And RI value is shown in Figure 3.

Size of Matrix (n*n)	1	2	3	4	5	6	7	8	9	10
Random Consistency (RC)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Figure 3: Random Consistency Index (Source:(Ali & Wali, 2020) [17]

As per [15], a ratio greater than 0.1 could be insufficiently inconsistent for the results to be relied upon. Therefore, CR must be below 0.1 or 10be reliable. The procedure must be repeated till the CR falls inside this range of values so that decision makers can come to a conclusion on the basis of a consistent judgement.

3. Research Methodology

3.1 Case-Study Area

3.1.1 Nagdhunga Tunnel Construction Project (NTCP)

Nagdhunga Tunnel is located in Nagdhunga, Chandragiri as shown in Figure 4. It is 2.67KM in length with 9.5m width and 18m height [18]. The excavation method for this tunnel is drilling and blasting (DBM). It is the Nepal‘s first Highway Tunnel.

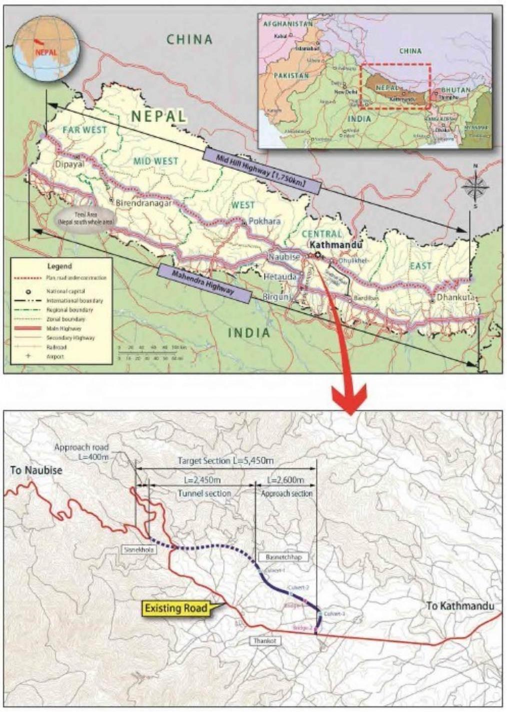

Figure 4: Location Map of Nagdhunga Tunnel (Source:JICA Report, March, 2015)

3.1.2 Bheri-Babai Diversion Multipurpose Project (BBDMP)

The Bheri Babai Diversion Multipurpose Project (BBDMP) is the first inter-basin water transfer project designed to provide year-round irrigation of 51,000 hectares of Banke land and Bardia region. So, it consists of two components: hydropower and irrigation. This includes construction of an intake at Chiple VDC Ramghat in Surkhet, a 12 km long tunnel through the youngest mountain range (i.e., Sivaliks), an equalizing shaft and a power plant at Hattikhal in Bardia. For the first time in Nepal, Tunnel Excavators (TBMs) are being used to drill through the soft rocks of Shivalik's. Recognizing its importance for Nepal's overall development, the Nepalese government named it as a National Pride Project. (Bheri Babai Diversion Multipurpose Project (BBDMP), n.d.). The tunnel length is 12206m in which 150m was excavated using DBM method and remaining 12056m was excavated using TBM method.

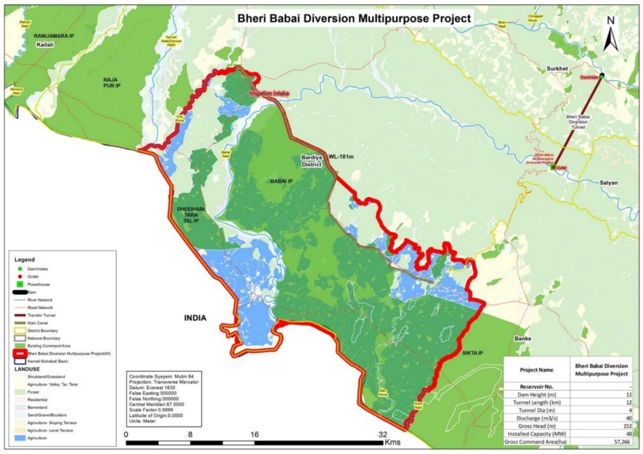

Figure 5: Location Map of Bheri-Babai Tunnel (Source:BBDMP Project)

3.2 Methodological Framework

The study's objectives will be to define and explore the primary focus of the research, which is the risk assessment of tunnel projects in Nepal. The methodology framework comprised of the following four parts: 1. Conception 2. Gathering information 3. Analysis of data 4. Conclusions and suggestions The first step in conducting the research is the stage of conceptualization, which shall be founded on the determination of the research area and the formulation of the problem statement. After that, a comprehensive literature evaluation on risk assessment of tunnel infrastructure is carried out to find the risk dimensions that affect the tunnel construction projects. During this stage, the research framework is going to be developed by identifying issues, actions, and the risk assessment process. The second part will be the stage of gathering information, that is a genuine and distinct part in research design. That will involve the kind and way of gathering information, including an interview with experts to validate the variables identified from the literature review. Third part utilizes AHP (Analytical Hierarchy Process) to analyze the collected data. With the aid of the third stage, the result and recommendations will comprise the final component.

3.3 Research Design

The research approach is both qualitative and quantitative. The qualitative method is used to identify risk dimensions and factors that affect the tunnel projects, and it develops into the quantitative method through the application of AHP to analyze data gathered on the value of each criterion of factors. It aids in analyzing the factors that influence the success of a tunnel project. AHP entails constructing a hierarchy of decision factors and then comparing potential pairings in a matrix to assign a weight to each element as well as a consistency ratio to assess the dependability of outcomes for the procedure of making decisions. Therefore, it seeks to create a comprehension of what and how various factors influence the success of tunnel construction projects. Such

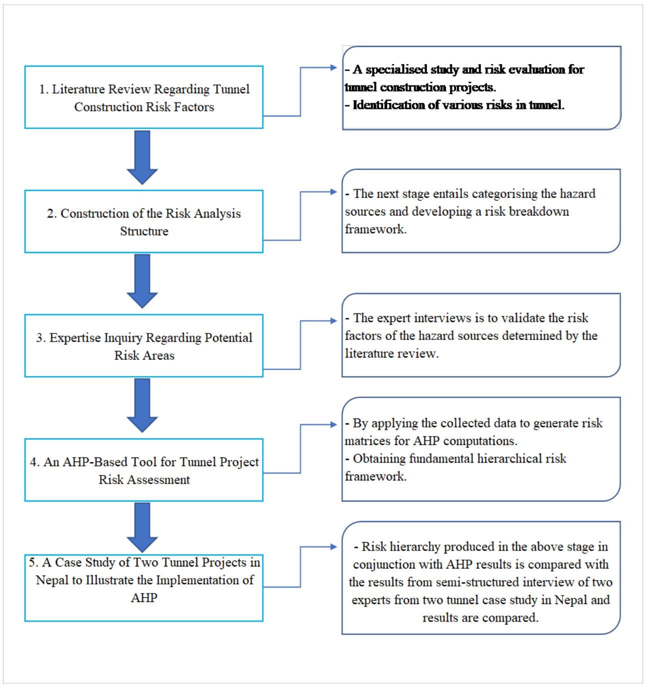

Figure 6: Methodological Framework

relationships are used to determine which factors have the greatest impact on the various stages of risk management.

3.3.1 Questionnaire Design

The extensive literature review and expert interviews assisted in determining the primary idea to investigate, discover research, and evaluate for the research, which contributed to the development of the framework. This framework for the defined research objectives will serve as a guide for conducting the research and developing the questionnaire. A questionnaire was disseminated to tunnel construction industry experts. The questionnaire will contain two sections: first section contains general demographic information such as name, position, academic qualification, years of experience, names of tunnel projects, etc. The second section of the questionnaire entails comparison of the relative importance of ten primary risk dimensions and thirty-three secondary risk factors. Respondents are required to provide relative scores for every factor in a comparison of all variables.

3.3.2 Data Collection

For data collection, a questionnaire was sent to 43 tunnel construction experts in Nepal. However, 36 questionnaires were received with 83.72response rate. Only 35 of 36 respondents' data were analyzed, omitting the data of one respondent with less than five years of experience. All other respondents were involved in at least two tunnel projects, and two of those who have worked in only one tunnel project have a master's degree and more than 16 years of experience in a managerial position.

3.3.3 Data Analysis

AHP is an effective instrument among MCDA for correlating factors in order to comprehend the degree of influence between multiple identified factors. AHP permits the

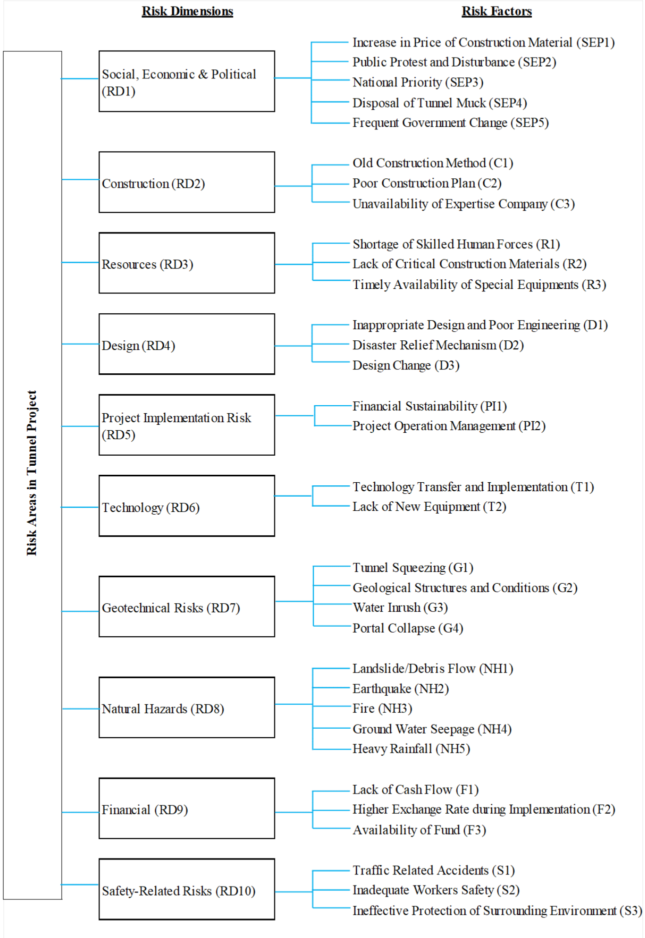

Figure 7: Hierarchial Structure of Risk Areas in Tunnel Project

breakdown of identified factors into multiple criteria and sub-criteria in a hierarchical structure. In this manner, each expert-confirmed criterion as shown in Figure 7 will be arranged hierarchically to determine the influence weight of each criterion. Hierarchy, rank, and weighting will be determined among the selected criteria for each factor using pairwise comparison form and AHP analysis format in Excel. According to the literature assessment, the weighting scale that the group of experts will be requested to designate will range from 1 to 9. Here, 1 represents a factor with equal relevance in comparison to other factors, while 9 represents the factor with the greatest impact as shown in Figure 2. Respondents will be asked to rank the relative relevance of each success criterion on the basis of the AHP scale.

4. Results and Discussions

The above data shows that geotechnical risks have the highest ranking followed by nat-ural hazards, safety-related risks, social, economic & political risks, etc. Technology has the lowest ranking among primary risk dimensions. λ_{max} = 10.292

and Consistency Ratio (CR) = 0.022 which is less than 10%. Thus the collected data are consistent.

The final hierarchial framework is shown in Figure 8.

Table 2: Relative Weightage of Primary Risk Dimensions

Code	Risk Dimension	Percentage Weight	Rank
RD1	Social, Economic & Political	14.09%	4
RD2	Construction	10.23%	5
RD3	Resources	3.74%	7
RD4	Design	3.04%	8
RD5	Project Implementation Risk	2.45%	9
RD6	Technology	2.24%	10
RD7	Geotechnical Risks	26.04%	1
RD8	Natural Hazards	15.44%	2
RD9	Financial	7.58%	6
RD10	Safety-Related Risks	15.13%	3

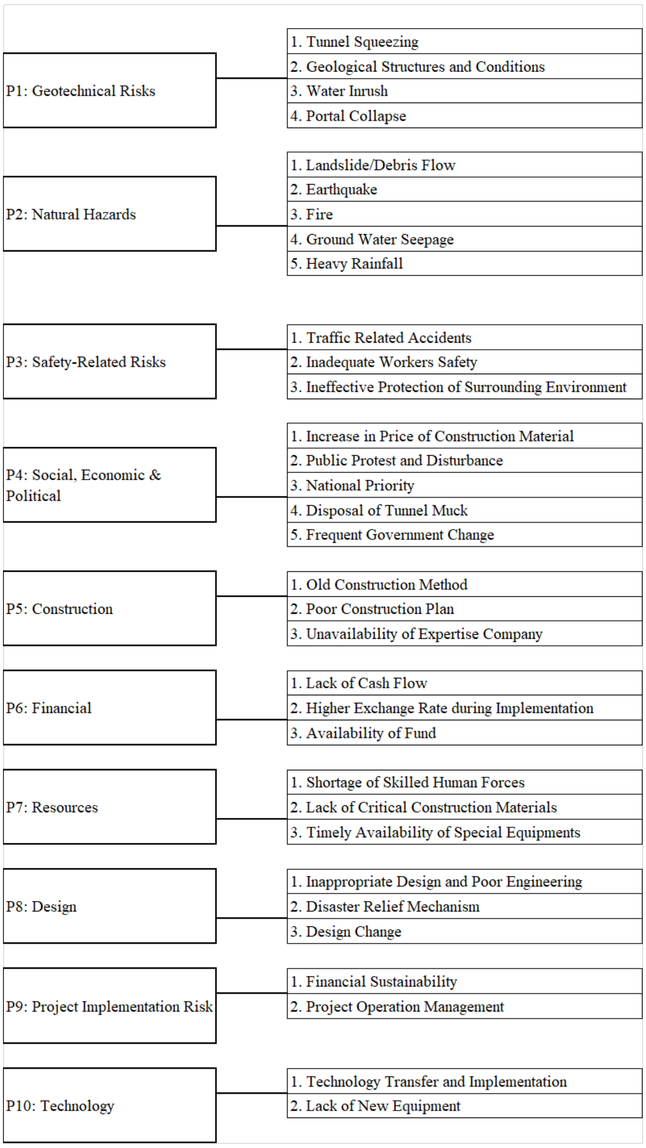

Figure 8: AHP Framework of Risk Areas in Tunnel Project

4.1 Primary Risk Dimensions

Among these primary risk dimensions, Geotechnical risk should be given priority during design and construction phase. Proper ground surface investigation shall be done to countermeasure the stress induced in support. Similarly, proper drain shall be made to prevent tunnel flooding and water seepages. The tunnel should have disaster relief mechanism to respond against disasters like earthquake, fire, landslide, etc. Also, workers safety and protection of surrounding environment is utmost important. Improper implementation of safety rules and regulations may cause accidents and death of workers.

Table 3: Relative Weightage of Secondary Risk Factors

Code	Risk Factors	Percentage Weight	Rank
Social, Economic and Political Risk (RD1)			
SEP1	Public Protest and Disturbance	33.27%	2
SEP2	Disposal of Tunnel Muck	10.79%	4
SEP3	National Priority	15.42%	3
SEP4	Frequent Government Change	5.08%	5
SEP5	Increase in Price of Construction Material	35.43%	1
Construction Risk (RD2)			
C1	Unavailability of Expertise Company	13.35%	3
C2	Old Construction Method	47.05%	1
C3	Poor Construction Plan	39.60%	2
Resources Risk (RD3)			
R1	Lack of Critical Construction Materials	28.74%	2
R2	Shortage of Skilled Human Forces	49.84%	1
R3	Timely Availability of Special Equipment	21.41%	3
Design Risk (RD4)			
D1	Inappropriate Design and Poor Engineering	42.22%	1
D2	Design Change	16.91%	3
D3	Disaster Relief Mechanism	40.88%	2
Project Implementation Risk (RD5)			
PI1	Financial Sustainability	56.10%	1
PI2	Project Operation Management	43.90%	2
Technology Risk (RD6)			
T1	Technology Transfer and Implementation	70.20%	1
T2	Lack of New Equipment	29.80%	2
Geotechnical Risk (RD7)			
G1	Geological Structures and Conditions	28.00%	2
G2	Water Inrush	11.37%	3
G3	Tunnel Squeezing	51.85%	1
G4	Portal Collapse	8.79%	4
Natural Hazards Risk (RD8)			
NH1	Earthquake	26.25%	2
NH2	Ground Water Seepage	9.86%	4
NH3	Heavy Rainfall	4.14%	5
NH4	Landslide/Debris Fall	45.11%	1
NH5	Fire	14.64%	3
Financial Risk (RD9)			
F1	Higher Exchange Rate during Implementation	30.96%	2
F2	Availability of Fund	9.88%	3
F3	Lack of Cash Flow	59.16%	1
Safety-Related Risk (RD10)			
S1	Inadequate Workers Safety	18.93%	2
S2	Ineffective Protection of Surrounding Environment	16.74%	3
S3	Traffic Related Accidents	64.33%	1

4.2 Secondary Risk Factors

- Due to the continual infiltration of water into the tunnel invert, the load-bearing ability of the earth's sediment near the invert falls, causing the concrete lining to fall to the ground, which in turn causes the squeezing of the tunnel support system causing increase in cost. Thus, a planned strategy must be taken when designing the drainage system in the tunnel invert. Due to the explosion and drilling technique, the faults and fractures present at rock mass become loosened, and as a result, the loosened rock material exerts a significant shear stress on the tunnel's intact rock mass, that can result in ruptures and fissures in the concrete lining. If serious defects or cracks exist, the tunnel's orientation needs to be altered rather than continuing along the same path. If orientation cannot be altered for unforeseen reasons, the gap between faults must be observed using the appropriate surveillance apparatus. If it surpasses the allowed limit, grouting needs to be implemented promptly.

- Natural hazards can cause disaster at any moment. The tunnel should be equipped with mechanisms for responding to natural disasters such as earthquakes, fires, landslides, etc.

- Usually, accidents in tunnel can occur due to insufficient airflow, deleterious gases, unnoticed geological vulnerabilities, mishandling of explosives, transporting sludge, etc. Thus, workers safety should be prioritized by the construction companies by providing appropriate Personal Protective Equipment (PPE), proper ventilation, flagman for equipment, safety cones, etc. Hit by the tunnel equipment and mucking dump truck can cause death of workers.

• During the construction phase, an increase in the cost of construction materials can result in budget overruns and disputes between clients and contractors. Similarly, project closures caused by public protests and disturbances can have a financial impact on the contractor and ultimately result in schedule delays. Frequent government changes and the prioritization of one project over another have a negative impact on the contractor's performance. Government should make a proper law to facilitate the smooth running of the project.

• In Nepal, the majority of tunnels are constructed using outdated methods. During the construction of a tunnel, incompetent workers and poor management can contribute to budget and time overruns. New tunnelling techniques, such as the use of TBM, can shorten the duration of construction.

• There is frequently an issue with clients, contractors, and subcontractors delaying payment, which can lead to disputes. Similarly, the problem of exchange rate fluctuations results in financial losses for projects undertaken by foreign companies. The exchange rate should be fixed so that there won't be any disputes.

• Inappropriate design and insufficient engineering practice can result in double the amount of effort and material consumption, resulting in a budget increase for the project. Inadequate disaster relief mechanisms, such as ventilation and emergency tunnel provision, can also result in casualties. An appropriate mechanism for disaster relief should be planned and incorporated into the design.

• After project turnover, the governing body lacks the necessary operational and financial expertise to manage the project efficiently. The project operation management team must receive appropriate training and technology transfer.

• The construction of tunnels projects has grown more extravagant over time. Engineers, human forces, and decision-makers must be taught how to use these emerging new technologies in order to keep up with their constant evolution.

5. Conclusion

Any tunnel project is a risk domain because of the unpredictability of all stages of construction. Considering the wide range and abundance of risks affecting tunnelling projects, it is evident that without a methodical and effective procedure for identifying and handling them, any effort to comprehend and regulate them is viewed with doubt, as is the outcome. In Nepal's construction industry, risk management is a relatively novel term. Through this research different risk areas in tunnel projects were identified and their relative importance was analyzed. Thus, the necessary critical risk factors for the successful completion of tunnel projects were outlined in the previous section and are suggested to the different company management teams and stakeholders seeking success in the tunnel construction sector in Nepal.

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