Journal of Engineering Issues and Solutions

Enhancing Tunnel Construction Efficiency in Nepal: Assessing Factors and Challenges

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Received: May 5, 2025; Revised: July 5, 2025; Accepted: July 12, 2025

https://doi.org/10.3126/joeis.v4i1.81560

Abstract

Nepal, situated amidst the Himalayas and bordered by China and India, faces significant challenges in economic development due to rapid urbanization and population growth. With its diverse topography, ranging from low-lying plains to towering peaks, the country's major economic resources, including water, agriculture, and tourism, necessitates infrastructural development. Tunnels play a crucial role in harnessing these resources, yet Nepal has historically relied on traditional drill-and-blast methods, hindering progress due to limited expertise and financial constraints.

This study examines the major challenges associated with drill-and-blast tunneling in Nepal, focusing on factors influencing over-break phenomena. Through a comprehensive analysis of existing literature and primary data collection from selected hydro-power projects, the research identifies key challenges such as army management, tunnel geology, and construction equipment limitations. Moreover, it investigates factors contributing to over-break, including powder factor, blasting pattern, and geological conditions.

The study highlights the need for optimized army management, local procurement of construction materials, and diversification of explosive suppliers to enhance efficiency and resilience in tunnel construction projects. Ultimately, this research contributes valuable insights to optimize tunnel construction methodologies and mitigate challenges, thereby fostering sustainable infrastructure development in the region.

Keywords: *Amidst, Constraints, Diversification, Hindering, Insight, Relied*

1. Introduction

Nepal, situated along the southern slope of the Himalayas and bordered by China and India, encompasses a land area of 147,181 square kilometers within the vast 594,400 square kilometers of the Himalayan region. With a length of approximately 890 kilometers from east to west and varying in width from 150 to 250 kilometers, Nepal's topography displays dramatic altitude shifts, ranging from 100 meters above sea level in the south to the towering peak of Mount Everest at 8,848 meters in the north (Panthi, 2006).

Despite its stunning natural beauty, Nepal faces challenges due to rapid population growth and urbanization, straining its economic development efforts. The nation's primary economic resources include water, agriculture, tourism, and aggro-tourism-based industries, necessitating crucial infrastructure development projects such as hydro-power schemes, irrigation systems, road networks, and drinking water systems. Moreover, the efficient utilization of underground space, including tunnels and caverns, is essential for maximizing resource utilization (Panthi, 2006).

While Nepal has a history of tunnel construction dating back to the 1970s, the adoption of advanced tunneling techniques, such as Tunnel Boring Machines (TBMs), gained momentum only recently, notably with the Bheri-Babai diversion tunnel project in 2018. However, the nation still faces challenges due to limited expertise and financial constraints, leading to continued reliance on traditional drill-and-blast methods for tunnel excavations, spanning 267 kilometers. Notable challenges associated with these methods include over-break – unintended damage to surrounding rock masses during excavation (NTA Conference 2019).

The design and construction of tunnels demand suitable technologies and techniques, often relying on field experience due to variable ground conditions. While drill-and-blast excavation remains cost-effective, it can lead to over-break issues, necessitating careful consideration and mitigation strategies. Geological and technical factors contribute to over-break, highlighting the complexity of tunneling projects in Nepal's rugged terrain (Singh and Xavier, 2005). Addressing these challenges is crucial for sustainable infrastructure development in the country.

Nepal's tunneling history reflects poor accuracy in geological investigations during planning phases, exacerbated by the Himalayan tectonic stress regime, resulting in intense rock deformation (Panthi, 2006). This geological complexity poses significant stability challenges for tunneling, with instabilities arising from geological and non-geological factors. Despite being the predominant method in Nepal, drill-and-blast excavation faces limitations, including high risk, delays due to over-break, and complex stakeholder coordination, emphasizing the necessity of deeper understanding and research in this area.

Tunnel excavation in Nepal heavily relies on the drill and blast method, a technique introduced by Tyrolean Kaspar Weondl in 1627. This method accommodates a wide range of rock types, making it suitable for various geological conditions encountered in Nepal's diverse terrain. Although traditional, it remains prevalent due to its versatility and effectiveness in both weak and high-strength rock environments. However, the adoption of advanced tunneling techniques like Tunnel Boring Machines (TBMs) has been limited, with drill and blast remaining the primary method due to factors such as feasibility and cost. Despite its widespread use, challenges such as over-break – unintended damage to surrounding rock masses during excavation – persist, necessitating careful consideration and mitigation strategies (NTA Conference 2019).

Drilling and blasting in tunnel excavation follow a systematic process involving several steps. Initially, blast holes are drilled into the rock at predetermined locations and depths. Explosives are then placed in these holes, followed by blasting to fracture the rock. Subsequently, loose rock debris is removed through mucking, and primary support installation is undertaken to ensure tunnel stability (Kolymbas, 2005). While this method offers versatility and relatively low capital costs, it requires meticulous planning and execution to mitigate risks associated with over-break and other challenges.

Over-break in tunnel excavation refers to the removal of rock material beyond the intended periphery, resulting in additional costs and structural risks. Factors influencing over-break can be categorized into rock mass variables and construction variables. Rock mass variables include discontinuity spacing, orientation, and strength, as well as in-situ stress conditions, which collectively influence excavation behavior (Chakraborty et al., 1996). Construction variables such as drilling pattern, powder factor, and explosive type also play a significant role in over-break occurrence (Kalamaras, 1996).

Various blasting techniques, including pre-splitting and line drilling, are employed to control over-break. Pre-splitting involves creating a shear plane in the rock before the main blast, ensuring controlled excavation along desired lines. Line drilling enhances excavation shaping by drilling alternate holes between main blast holes, facilitating accurate tunnel profiles. However, despite these techniques, tunnel collapses remain a concern, especially at the portal, along the tunnel length, and at the active excavation face (Tun and Singal, 2016).

The existing literature on the drill and blast method in tunnel excavation, particularly in Nepal's context, is limited. This research aims to address this gap by exploring the nuances of the drill and blast method, identifying key challenges, and factors influencing over-break in drill and blast method of tunneling in Nepal. By delving into factors influencing over-break and assessing blasting techniques, this study seeks to enhance understanding and optimize tunnel construction processes in Nepal's rugged terrain.

2. Materials and Methods

The research design aimed to investigate factors affecting over-break in tunnel construction and challenges of drill-and-blast methods in hydro-power projects. Four ongoing hydro-power projects in Nepal were selected as the study area. A literature review provided insights into relevant challenges. Primary data collection involved discussions with project managers, construction managers, and senior geologists, alongside structured questionnaires and key informant interviews. Secondary data sources included progress reports of the selected projects. A quantitative approach was adopted, utilizing standardized questionnaires to address drill-and-blast method challenges. The study population comprised technical personnel involved in underground tunnel construction, totaling 186 individuals across the four projects. Discussions and interviews provided insights into challenges, and questionnaires aided in data collection. These methods ensured a comprehensive understanding of factors influencing over-break and challenges in tunnel construction, contributing to the study's research objectives.

Table 1: Details of Selected Hydropower Projects

S.N	Description	Middle Mewa Hydropower Project	Lower Solu Hydropower Project	Solu Khola Dudhkoshi Hydroelectric Project	Ghar Khola Hydroelectric Project
1	Project location	Taplejung district	Solukhumbhu district	Solukhumbhu district	Myagdi District
2	Installed Capacity	49 MW	82 MW	86 MW	14 MW
3	Type of Project	PROR	ROR	ROR	ROR
4	River	Mewa Khola	Solu Khola	Solu Khola	Ghar Khola
5	Total annual energy	290.76 GWH	463.202 GWH	520.20 GWH	78.65 GWH
6	Design Discharge	12.56 m3/s	20.42 m3/s	17.05 m3/s	3.46 m3/s
7	Gross Head	475	491	613.2	485
8	**Headworks**				
9	Dam/Weir	Dam	Barrage	Weir	Weir
10	Dimension	233.5m x 21m	62.5mx73mx7.5m	34.8 mx 13.5m	
11	**Intake**				
12	No of Intake	1	2	3	
13	Opening dimension	8.0m x2.5m	3m x 2.7m	4mx 2m	
14	**Desander**				
15	No. of Bay	3	2	3	
16	Dimension	75.6mx8.5mx.8.5m	104.8mx6.6mx11.6m	85m x 9m x 5m	
17	**Headrace tunnel**				
18	Length	5.4 km	4.3 Km	4.469 Km	
19	Dimensoin	3.8mx 4.10m	3.2m x3.2m	4m x 4.25 m	
20	Shape	Inverted D	Inverted D	Inverted D	
21	**Surgeshaft/ Surge tunnel**	surgeshaft	surgeshaft	surge tunnel	
22	Height	39m	72m	375m	
23	Finish Dia	6m	8m	4m x 4m	
24	**Penstock Pipe**				
25	Length	1150m	1475 m	1867.17 m	1200m
26	**Powerhouse**				
27	Type	Underground	Surface	Surface	
28	No of unit	3	2	3	2
29	Type of turbine	Pelton	Pelton	Pelton	
30	Axis of turbine	Vertical	Vertical	Vertical	
31	**Transmission Line**				
32	Voltage level	132 KV	132 KV	132 Kv	
33	Length	15 KM	4.12 KM	12 m	
34	Developer	Mewa Developers Ltd.	Solu Hydropower Pvt. Ltd.	Sahas Urja Ltd.	Myagdi Hydropower Ltd.
35	Status of Project	Under construction	Under Construction	Operation	Operation

2.1 Sample Size for the hydro-power projects and technical personnel

The sample size for the research will be taken as 4 for hydro-power projects. Using the Israel formula, a sample size of 65 was chosen for further study, distributed equally among the four hydro-power projects.

The sample population consists of 186 individuals selected from four specified projects. According to the Israel formula, a sample size of 65 will be chosen for further study.

$n = z^2 pq/e^2 / 1+(z^2pq/e^2N)$ (Israel, 1992)

Where, n = Sample Size

z = 1.96 for 95% Confidence Level

p = 0.5, q=0.5, e = Margin of error, using 10% error margin.

n= 65

The sample size, which is 35% of the overall study population, will be equally distributed among all four hydro-power projects for research purposes.

The complete sample size for the four hydro-power projects was then distributed among each project's personnel who will participate in the questionnaire and interview processes, aligning with research objectives through the utilization of the Proportionate Random Sampling method.

Table 2: Number of Respondents for Survey within each projects

S.N.	Name of Project	Population	Sample	% distribution
1	Middle Mewa Hydropower Project- 49 MW	50	18	28%
2	Lower Solu Hydropower Project – 82 MW	55	19	29%
3	Solukhola Dudhkoshi Hydroelectric Project- 86 MW	55	19	29%
4	GharKhola Hydropower Project- 14 MW	26	9	14%
5	**Total**	**186**	**65**	**100%**

Questionnaire, key informant interview and focus group discussion were conducted among major stakeholders.

2.2 Data analysis

Data collected from primary and secondary sources undergo summarization, classification, tabulation, and categorization. Analysis is conducted individually for each project and collectively for all four. MS Office tools and Excel are utilized for data derivations, with outcomes presented through tables and charts. Both descriptive and inferential statistics are employed. The General ranking method determines the importance of challenges in drill and blast in Nepal, alongside factors influencing over-break in tunnel construction, using Likert's scale for calculating mean RII. For data analysis RII is used by following equation:

$RII = W / A*N \quad (0 \leq RII \leq 1)$

Where: W – The weight given to each factor by the respondents and ranges from 1 to 5, (where "1" is "strongly disagree" and "5" is "strongly agree")

A – The highest weight (i.e., 5 in this case) and N – The total number of respondents

3. Results and Discussion

3.1 Combined Ranking of the identified factor influencing over-break in tunneling

The factors influencing over-break in tunnel construction have been identified and documented through a thorough literature review and Key Informant Interviews (KII) involving various professionals in the Nepalese tunnel construction sector. These identified factors have been integrated into a questionnaire survey, enabling the ranking of these factors to determine their relative importance in drill and blast methodologies. The comprehensive rankings for factors influencing over-break in tunneling, specifically related to drill and blast methods, are presented in Table 3. These rankings are based on evaluations from personnel at the supervisor level and above, representing contractors, consultants, and clients with significant tunneling expertise. Notably, all factors across the four selected hydro-power projects in Nepal have Relative Importance Index (RII) values exceeding 50%.

Table 3: Overall Ranking of the identified factors influencing over-break of selected 4 hydro-power projects

S.N	Description	Middle Mewa HEP		Ghar Khola HEP		Lower Solu HEP		Solu Dudhkoshi HEP		Combined	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Powder factor	0.978	I	0.933	I	0.926	I	0.958	I	0.948	I
2	Blasting pattern	0.956	II	0.911	II	0.884	III	0.874	II	0.906	II
3	Depth of drill	0.889	III	0.844	III	0.874	IV	0.853	IV	0.867	III
4	Number of discontinuity	0.844	VI	0.778	VI	0.800	VII	0.789	VI	0.803	IV
5	Discontinuity spacing	0.867	IV	0.822	IV	0.800	VIII	0.811	V	0.827	V
6	Tunnel shape and size	0.856	V	0.800	V	0.895	II	0.853	III	0.858	VI
7	Discontinuity strength	0.800	VII	0.756	VIII	0.811	VI	0.789	VII	0.794	VII
8	Discontinuity orientation	0.800	VIII	0.733	IX	0.832	V	0.737	IX	0.782	VIII
9	Horizontal and vertical stress ratio	0.778	IX	0.756	VII	0.726	IX	0.758	VIII	0.755	IX

Figure 1 below shows the bar diagram of the identified factors influencing over-break in the drill and blast method of tunneling of selected four hydro-power projects with their respective RII.

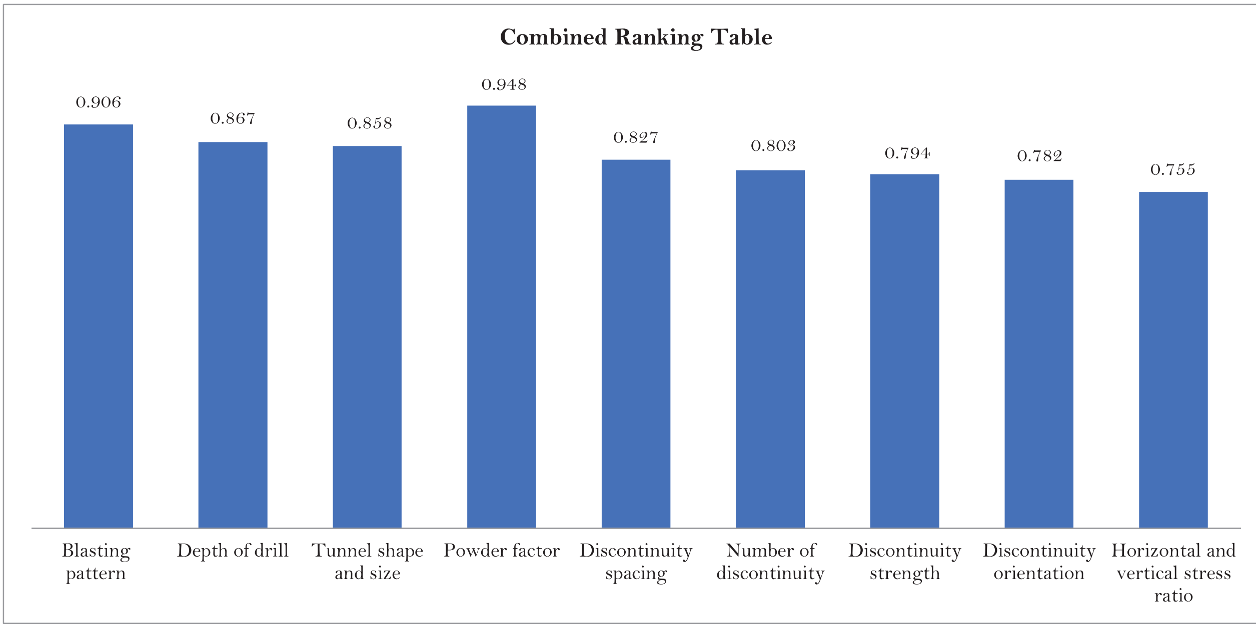

Figure 1: Overall Ranking of the identified factors influencing over-break

3.1.1 Powder factor

The powder factor emerges as the most influential factor in over-break in tunneling, ranking first with an RII of 0.948 (Table 3, Figure 1). Consistency in rankings is observed across Middle Mewa (RII=0.978), Ghar Khola (RII=0.933), Lower Solu (RII=0.926), and Solu Dudhkoshi (RII=0.958). Powder factor, defined as explosive mass per cubic meter of rock, governs tunnel construction productivity. Loading explosives optimally for each blast cycle is crucial, determined by experienced tunnel foremen in collaboration with experts, based on rock type, drill depth, explosive quality, and blasting pattern.

3.1.2 Blasting Pattern

The blasting pattern ranks as the second most influential factor in over-break in tunneling, with a top rank of RII=0.906 (3.1, Figure 1). Consistent rankings are observed for Middle Mewa (RII=0.956) and Ghar Khola (RII=0.911), as well as Lower Solu (RII=0.884) and Solu Dudhkoshi (RII=0.874). Drilling patterns dictate hole advancement, categorized by rock type, and arranged systematically to achieve desired results. Wedge cut drilling is common, while burn cut drilling suits tunnels with favorable geology. Blasting pattern, influenced by drilling pattern, affects over-break by guiding hole angles and spacing.

3.1.3 Depth of Drill

The depth of the drill ranks third in influencing over-break in tunneling, with an RII of 0.867 (Table 3, Figure 1). Consistent rankings are observed across Middle Mewa (RII=0.889), Ghar Khola (RII=0.844), Lower Solu (RII=0.874), and Solu Dudhkoshi (RII=0.853). In drill and blast tunnel construction, the depth of each drilling cycle significantly impacts over-break. It's determined by experienced geologists or experts based on rock type and drilling machine capacity. Weak rock requires shallower drilling, while stronger rock necessitates deeper drilling. Longer drilling depths increase over-break likelihood in tunnels.

Figure 2: Drilling Equipment

3.1.4 Number of discontinuity

Number of discontinuity have fourth rank with RII=0.803 as shown in the Table 3. There is consistency of ranking among Middle mewa (RII =0.844) and Lower solu (RII = 0.800) . Correspondingly, There is consistency of opinion among Ghar khola (RII = 0.778) and Solu dudhkoshi (RII = 0.789). Number of discontinuity also another parameter to determines the over-break. As the discontinuity number is more there will be high chances of occurring over-break even in controlled construction operation. More the fracture weak will be rock eventually, rock mass properties will be lower resulting the short stand-up time. Number of joint sets determines the quality of rock which is very determining factors for over-break in tunnel.

3.1.5 Discontinuity spacing

Discontinuity spacing ranks fifth with an RII of 0.827, significantly impacting over-break in tunneling via the drill and blast method (Table 3, Figure 1). Middle Mewa (RII = 0.867), Ghar Khola (RII = 0.822), Lower Solu (RII = 0.800), and Solu Dudhkoshi (RII = 0.811) maintain consistent rankings. Discontinuities, representing weak planes within rock masses, vary from small fissures to large faults, common in Nepal's sedimentary and metamorphic rocks. Young geological strata in Nepal exacerbate discontinuities, leading to increased over-break and weakened rock masses, especially at joints between strata. The spacing of discontinuities directly correlates with over-break occurrence, posing challenges in tunnel stability and construction efficiency.

3.1.6 Tunnel shape and Size

Tunnel shape and size have sixth rank with RII=0.858 influencing over-break in the drill and blast method of tunneling as shown in the Table 3 and Figure 1.As shown in the Table 3, there is consistency of ranking among Middle mewa (RII =0.856), Ghar khola (RII = 0.800), lower solu (RII = 0.895) and Solu dudhkoshi (RII = 0.853). Tunnel shape and size also have importance role in over-break . As higher sizes of tunnel longer peripheral surface which might be detached from the original rock mass increasing the high chances of over-break additionally, shape of tunnel. Tunnel with self-stable shape have low chances of over-break as compared to other. Mostly, tunnel with circular, horse shoe shape most stable shape in compared to the square or rectangular shape.

3.1.7 Discontinuity strength

Discontinuity strength have seventh rank with RII=0.794 influencing over-break in the drill and blast method of tunneling as shown in the Table 3 and Figure 1. As shown in the Table 3, there is consistency of ranking among Middle mewa (RII =0.800) and lower solu (RII = 0.811). Correspondingly, There is consistency of opinion among Ghar khola (RII = 0.756), and Solu dudhkoshi (RII = 0.789).Strength of each layer is depends on the type of rock. Normally higher the individual strata of rock determine rock quality which eventually leads for over-break in tunnel. Higher the individual rock strength less will be chances of over-break in tunnel. However, many working process are interlinked to cause the over-break in tunnel.

3.1.8 Discontinuity orientation

Discontinuity orientation have eighth rank with RII=0.782 influencing over-break in the drill and blast method of tunneling as shown in the Table 3 and Figure 1. As shown in the Table 3, there is consistency of ranking among Middle mewa (RII =0.800) and lower solu (RII = 0.832). Correspondingly, There is consistency of opinion among Ghar khola (RII = 0.733), and Solu dudhkoshi (RII = 0.737).Tunnel excavation direction will be set by tunnel expert based on the available geological data however, while choosing the tunnel excavation orientation one of the most important parameter id discontinuity orientation. Discontinuity orientation will be positive and negative impact on the tunnel excavation health along with the cause of over-break. Favorable tunnel orientation will reduces the over-break eventually increase the productivity in tunnel excavation.

3.1.9 Horizontal and Vertical Stress ratio

Horizontal and Vertical Stress ratio ranks as the least significant factor in tunneling over-break with an RII of 0.755 (Table 3, Figure 1). Middle Mewa (RII = 0.778), Solu Dudhkoshi (RII = 0.758), Ghar Khola (RII = 0.756), and Lower Solu (RII = 0.726) maintain consistent rankings. Vertical stress, influenced by tectonic stress and burial depth, increases rock damage. Adequate tunnel cover mitigates stress effects, yet stress-induced fractures remain a concern. Excavation elevates stress, leading to over-break and potential rock bursting incidents. Despite design efforts, stress-related challenges persist, necessitating careful management to minimize over-break occurrences during tunnel construction.

3.2 Combined Ranking of the identified challenges in drill and blast method of selected four hydro-power projects

Key Informant Interviews (KII) with various tunnel construction professionals in Nepal have documented primary challenges in tunnel construction. These challenges were incorporated into a questionnaire survey to rank them based on importance. Table 4 shows rankings from supervisor-level and above personnel in four hydro-power projects. All challenges have Relative Importance Index (RII) values over 50%, highlighting their significance in drill and blast tunneling methods in Nepal. This underscores the importance of addressing these challenges for successful tunnel construction projects.

Table 4: Overall Ranking of the identified challenges in drill and blast methods of selected four hydro-power projects

SN	Description	Middle Mewa HEP		Ghar Khola HEP		Lower Solu HEP		Solu Dudhkoshi HEP		Combined	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Army management	0.989	I	0.933	I	0.905	II	0.958	I	0.942	I
2	Explosive management	0.978	III	0.933	II	0.905	III	0.905	II	0.930	II
3	Tunnel geology	0.978	II	0.911	III	0.916	I	0.863	IV	0.915	III
4	Construction equipment	0.900	V	0.889	V	0.842	VI	0.874	III	0.876	IV
5	Explosive quality	0.878	VI	0.844	VII	0.863	IV	0.863	V	0.864	V
6	Tunnel shape and size	0.900	IV	0.889	IV	0.821	VII	0.800	VII	0.848	VI
7	Construction manpower	0.844	VII	0.867	VI	0.853	V	0.842	VI	0.848	VII
8	Construction materials	0.822	VIII	0.733	VIII	0.716	VIII	0.726	VIII	0.755	VIII

Figure 3 below shows the bar diagram of the identified challenges of selected four hydro-power projects.

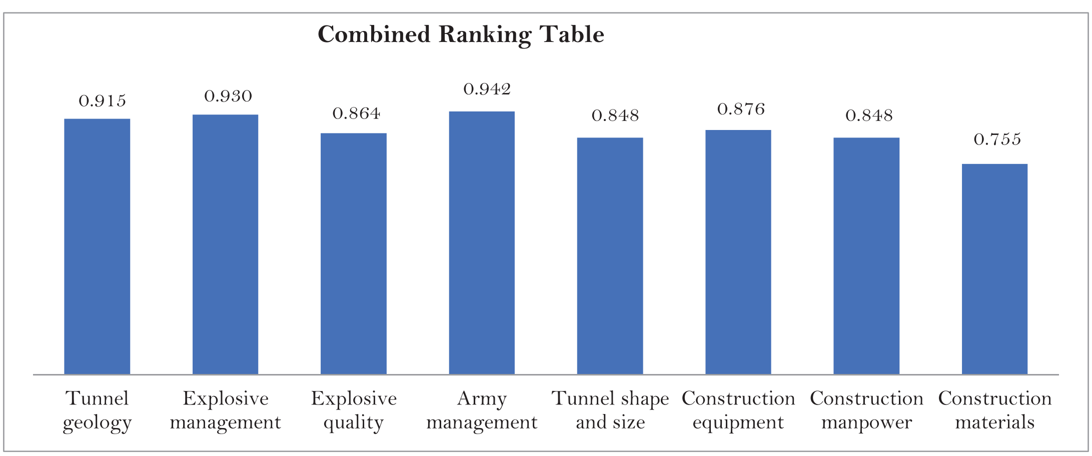

Figure 3: Overall Ranking of the identified challenges of selected four hydro-power projects

In the context of tunnel construction research in Nepal, a thorough examination of eight distinct challenges reveals key insights from the four selected hydro projects. The paramount concern affecting tunnel construction is identified as army management, holding the highest Relative Importance Index (RII) at 0.942. Following closely, explosive management emerges as the second most significant challenge, attaining an RII of 0.930.

Notably, tunnel geology is ranked third in importance with an RII value of 0.915. Conversely, construction material proves to be the least significant challenge in tunnel construction, garnering an RII value of 0.755. This research underscores the critical impact of army and explosive management on tunnel construction in Nepal, providing valuable insights for further investigation and mitigation strategies.

3.2.1 Army management

Army management poses the foremost challenge in tunneling using the drill and blast method, ranking first with an RII of 0.942 (Table 4, Figure 3). Consistency in rankings is evident among Middle Mewa (RII = 0.989), Ghar Khola (RII = 0.933), Lower Solu (RII = 0.905), and Solu Dudhkoshi (RII = 0.958). Explosives required for tunneling are procured by licensed agencies, whether from outside Nepal or the Nepali Army factory, then transported to dedicated bunkers under army supervision, adhering to Nepalese law. Army officers ensure security during procurement, transportation, and storage in nearby bunkers. Their presence is also essential during explosive escorting into tunnels and blasting, alongside Nepal Police, adding complexity and resource intensiveness to tunnel construction in Nepal.

3.2.2 Explosive management

Explosive management ranks second with an RII of 0.930 (Table 4, Figure 3), with consistent opinions among Middle Mewa (RII = 0.978), Ghar Khola (RII = 0.933), Lower Solu (RII = 0.905), and Solu Dudhkoshi (RII = 0.905). In tunnel construction via the drill and blast method, ANFO is commonly used, alongside emulsion explosives of various diameters and weights. While Indian suppliers primarily fulfill explosive requirements, the Nepalese army's plant in Hetauda also contributes. However, procurement of detonators, crucial for blasting, is solely from Indian suppliers. This complex procurement involves coordination among various government entities, including the Nepali Army, Home Ministry, Foreign Ministry, and others. Obtaining a No Objection Certificate from the Indian embassy adds time, complicating timely explosive delivery. Such intricacies often lead to project delays due to explosive unavailability, highlighting the challenges in hydropower project tunnel construction.

3.2.3 Tunnel Geology

The tunnel geology is found to be the third most significant challenge in the drill and blast method of tunneling having third rank with RII=0. 915 as shown in the Table 4 and Figure 3. As shown in the Table 4, there is consistency of ranking among Middle mewa (RII =0.978), Ghar khola (RII = 0.911), Lower solu (RII = 0.916) and Solu dudhkoshi (RII = 0.863). The tunnel geology is very important parameter that determines the productivity in tunnel construction. Being as very young rock type of abundantly sedimentary and metamorphic rock having thin to thickly jointed rock mass creates problem in tunnel excavation with vast variation in tunnel alignment cause problem in tunnel excavation.

Figure 4: Tunnel Geology

3.2.4 Construction Equipment

Construction equipment ranks fourth with an RII of 0.876 (Table 4). Middle Mewa (RII = 0.900) and Ghar Khola (RII = 0.889) maintain consistent rankings, as do Lower Solu (RII = 0.842) and Solu Dudhkoshi (RII = 0.874). Hand-held drills, particularly jackhammers, are commonly used underground for their cost-effectiveness. These drills, manually operated or with a pusher leg attachment, can bore holes ranging from 25mm to 50mm in diameter, with a maximum depth of 4m (practical limit being 3m). Drifter drills, featuring hammers sliding on booms, are also utilized, primarily for vertical and horizontal drilling. Equipment, mainly imported from India and China, includes mucking tools like hagg loaders, wheel loaders, and backhoe loaders. However, challenges persist in acquiring the right equipment, spare parts, and managing costs, significantly impacting tunnel construction timelines in Nepal due to limited availability in the local market.

Figure 5: Tunnel Equipment

3.2.5 Explosive Quality

Explosive quality have fifth rank with RII=0.864 as shown in the Table 4. There is consistency of ranking among Middle mewa (RII =0.878), Ghar khola (RII = 0.844), Lower solu (RII = 0.863) and Solu dudhkoshi (RII = 0.863). Another challenge of quality of explosive is very important for tunnel construction and its productivity in tunnel works. The quality of explosive delivered by Indian Supplier like Solar Company, Orica Company is comparatively better than the quality of emulsion supplied from Nepali Army. The quality delivery of explosive plays very crucial role in tunnel construction both qualities of works along with safety. The good quality of explosive will makes better working environment in tunnel by making less gas production in blasting leading to safe and better working environment for tunnel works.

Figure 6: Explosive for Tunnel

3.2.6 Tunnel shape and Sizes

Tunnel shape and sizes rank sixth with an RII of 0.848 (Table 4). Middle Mewa (RII = 0.900), Ghar Khola (RII = 0.889), Lower Solu (RII = 0.821), and Solu Dudhkoshi (RII = 0.800) maintain consistent rankings. Tunnel construction is influenced significantly by shape and size, where larger tunnels entail higher excavation risks. Tunnel shape also impacts construction ease and stability. Most tunnels range from 2 to 6 meters, except for those supporting hydro-power capacities exceeding 100 MW. Common shapes like Inverted D and horseshoe ease construction but may compromise self-stability, unlike the circular shape. Optimal designs balance stability with construction challenges, affecting equipment movement and over-break control.

Figure 7: Inverted D shaped tunnel of Lower Solu hydro-project

3.2.7 Construction Manpower

Construction manpower ranks seventh with an RII of 0.848 (Table 4). Middle Mewa (RII = 0.844), Ghar Khola (RII = 0.867), Lower Solu (RII = 0.853), and Solu Dudhkoshi (RII = 0.842) maintain consistent rankings. Drills, supervisors, operators, and mechanics constitute essential construction manpower for specialized tasks. While Nepal's market offers some specialized manpower, it falls short of the requirements for tunnel construction. Reliance on Indian or Nepali workers with experience from India becomes necessary. The scarcity of specialized manpower, coupled with the introduction of new imported equipment unfamiliar to local workers, poses hiring and management challenges, further complicating tunnel construction in Nepal.

3.2.8 Construction Materials

Construction materials is the least significant factor having eighth rank with RII=0.755 as shown in the Table 4. There is consistency of ranking among Middle mewa (RII =0.822) and Gharkhola (RII = 0.733). Correspondingly, There is consistency of ranking among Solu Dudhkoshi (RII = 0.726) and Lower solu (RII = 0.716). Due to vast development in the construction industry like manufacture of cement and reinforcement in Nepal it make some kind of ease in construction however, some special chemicals like micro-silica, admixture, accelerator which is specially required for shotcrete and high grade concrete needs to import from outside country. This creates problems in construction works due to availability of those materials.

Figure 8: Wire mesh for Tunnel support

4. Conclusions

Nine factors influencing over-break in the drill and blast method of tunneling in Nepal were identified, with powder factor emerging as the most significant determinant, impacting tunnel construction productivity by regulating the explosive mass per cubic meter of rock. Factors like blasting pattern, drill depth, and discontinuity spacing also played crucial roles. Conversely, the horizontal and vertical stress ratio was deemed the least influential factor, though stress conditions due to depth could still cause fractures and over-break incidents, underscoring the importance of careful design. The most significant challenge identified was army management, with explosive procurement and transportation involving coordination with various agencies and strict security protocols. Tunnel geology, construction equipment, and explosive quality also posed major challenges, while construction materials presented relatively fewer obstacles due to local availability. Strategies to mitigate over-break encompassed specialized techniques like forepoling, managing powder factor, and employing presplitting methods. Other approaches included pre-consolidation grouting, probe drilling for geological analysis, and adapting blasting patterns. Immediate support measures like shotcrete application were also emphasized. These findings provide a comprehensive guide for effective over-break control in tunneling projects, offering practical insights to the industry.

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