Review of Underground Space Utilization and its Relevance in Nepal

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Abstract

Underground space, both open-cut and fully underground method, has been in use throughout the world for mining, storage, waterway, transport, and others from past centuries. But still the clear demarcation of ownership in terms of surface and underground is not clear in most parts of the world. The concept of underground space utilization is an evolving concept. The developed nations have opted for this option to accommodate growing urbanization need. Two modes of space utilization are reviewed for this paper, open excavation and full underground excavation. Also world case scenario is presented and is compared to the situation in Nepal. Social factors and geological factors in the context of Nepal are also addressed that have been crucial in case of some completed projects. Ambiguous underground rights in relation to surface ownership in Nepal is taken in account and example of some cities like Singapore, Tokyo, Helsinki is presented to make it clear how right segregation is possible and is needed for better underground space utilization. Historical evolution of Tunneling in Nepal is discussed along with the future designed and scheduled projects. Despite the geological complexity and lack of experienced manpower in the context of Himalayan geology the importance of underground space is highlighted because emerging researches and technological innovation around the world and also in Nepal have been confirming this concept now and again. As a conclusion for betterment and well managed cities in Nepal underground space would be an undefeated option in the long run.

Keywords: *Tunnelling in Nepal, Underground Space Utilisation, Urbanization*

Introduction

According to the 1996 report from the Finish Ministry of Environment, Underground space stands for space under the ground. Ground-level which in pure geological terms is the normal ground elevation, which is also the intermediate zone for surface and underground. Space is the built and unbuilt structures in both regions (Ronka et al., 1998).

In construction practice, there are two ways to go underground, one by open excavation, and the second is fully underground. In open excavation, the ground surface is cut deeper than the existing ground level creating space such as basements, trench, or open pit. In the latter case, space is created by excavating inside the bed-rock or soil cover from an existing ground surface, like cavern or tunnels (Ronka et al., 1998). Both cases are constantly used and improved in the present situation depending on where they are designed. In addition to that, based on purpose underground space can be subdivided into networks, transportation, storage and shelter & others (Zerhouny et al., 2018).

According to Peter Stones (2016), social drivers like economic growth, population growth, livability improvement, preservation of surface heritage and connectivity enhancement, and social pressures like land shortage, influx in urbanization, high cost which are independent of place and geography will always push the designer to see underground space as new solution.

In context with above analysis, Kathmandu also has only two options left, either to increase the height of the building or expand the floor area. Considering the present scenario in lieu with urbanization trend, surface-based design appears less promising. In relation to that, open cut method can be a partial solution regarding network installation. Eventually, if considered this option for all the driving pressures, cost will be high as all the loads are to be taken by external support structures. The problem of surface constraint will again rise after certain time. In such cases, the second option snakes its way in as a viable solution. In good ground conditions, the rock itself can be designed as a supporting element. However, the limitation of not having the stable bedrock condition and unpredictable geology are some issues that need to be dealt on site basis but in overall, the flexibility supersedes the constraints when going underground.

Underground Space

Underground space is classified based on function, geometry, origin, site, and its features (Goel et al., 2012). Based on space utilization there are Open-cut methods and fully underground methods. Open-cut excavation expands from open-pit mining to an open trench system. In an open mining system, surface excavation is left open for a duration of mining activity. An open trench is a traditional option where new structures or systems are installed in the excavated trench and then backfilled to restore the surface. Modern utility options like water supply and drainage pipe, cable ducts, etc. are mostly installed in this pattern due to its ease of construction, repair or replacement.

Tunneling in shallow and deep underground relies largely on the geological/bedrock conditions. The general philosophy is that rock itself can be modeled as a load-sharing element. Once the equilibrium of the rock mass is disturbed by creating the void, the resulting forces are shared between external support structures and the rock itself (Nilsen & Thidemann, 1993). Space is then connected with the ground surface via horizontal (roads) or vertical (lifts or staircases) openings. This method turns out to be a cheaper solution than building all new structures like on the surface. It all depends on how good the geology is and where the design is being planned. But sometimes in busy cities like Paris, Oslo, Tokyo, London, and other emerging cities it is not even an option to think otherwise than to opt for underground spaces. Cities which has chosen this technology are still intact sufficing the growing needs and keeping the old décor and culture intact above the surface.

Requirements for the Underground Space

Geological condition is the primary requisite in designing underground space. In addition, parameters such as shape, position, geometry, and purpose are considered the governing factors for the designers when dealing with underground space (Goel et al., 2012). Besides that there are also social drivers and pressures that determine relevance of underground space. The key issue is to know the geological features beforehand. As presented earlier the purpose of space created or designed underground has to have clear demarcation, so that the factor of safety and the support condition can be allocated correctly. Too shallow excavation will lead to groundwater issues, unstable surface, and too high overburden will create in-situ stress problems in addition to other challenges if not tackled properly.

The psychological aspect of underground space is another challenge and concern governing the design. Designers then have to know who and how they are going to treat it keeping in mind the end use sharing of the space. Underground space utilization can be segregated based on public interaction and mobility. With this approach, the tunnel cost due to the factor of safety can be brought down to the feasible space compared to that of alternative surface space utilization. Though underground space has three-dimensional freedom, the access point is restricted by the stable valley side and topographical features (Goel et al., 2012).

Pros and Cons of Underground Technology

Location, design flexibility, land use efficiency make the underground space an attractive choice (Goel et al., 2012). An underground storage facility can provide stable climatic conditions despite the varying surface climatic conditions. Studies in Turkey showed that caverns in granite with overburden can reduce the energy cost for cold storing of the food, and Tuff geology is expected to work better with frozen food (Unver & Agan, 2003). In addition to that tunnels can be used for transport, water & wastewater supply, basic utility space, etc. Underground space can also be a safe refuge from war and natural calamities if equipped with proper ventilation with sufficient humidity and enough lighting to make everyone comfortable. Co-ordination of surface and underground space utilization is a must as underground space development is highly likely to affect the above ground uses in the form of space for access & ventilation (Stones & Heng, 2016).

It is implied understanding that rock engineering projects can be extended, upgraded, maintained, or repaired but hardly rehabilitated (Ronka et al., 1998). Also, it is a permanent structure, unlike surface ones. The initial cost is on the higher side and the final cost varies due to geological uncertainty. Despite having three-dimensional freedom, topography plays a significant role in positioning the entrance to space which affects the overall cost and feasibility of the project itself.

Review of World Cases

In the ancient times underground space was used in the form of storage cellars, bunkers, access between the buildings, dungeons, etc. Underground space utilization can be traced from Malpas Tunnel on Canal du Midi built in the late 17th century to The Saint Gothard Tunnel in Switzerland built around the late 19th century. However, the London underground road was the first to be constructed in the core of the city space to bypass the horse-drawn traffic problem (Besner, 2017).

In recent years, Laerdal road tunnel with 24.5 Km in Norwegian mountains, St. Gotthard tunnel 16.9 Km and Twin Bore Gotthard base rail tunnel with 57 Km in Switzerland positioned under Alps mountains are prominent project in the tunnel industry (AG, 2016; Grimstad & Bhasin, 1999). The importance of the projects could be more illustrated with the methodology like NATM, NMT that resulted from working in similar geology for a long time. The new Austrian Tunneling Method (NATM) stabilizes the tunnel with a controlled stress release technique and is very appropriate in soft ground conditions. Norwegian Method of Tunneling (NMT) works aptly in good rock conditions in combination with bolt and fiber-reinforced shotcrete as an immediate and final support system (Singh & Goel, 2011).

As per Bobylev and Sterling (2016), in recent years search for scholarly article for Urban underground space (UUS) has increased exponentially and in number of search china is the leading country trailing behind are USA and Japan. Keeping the numbers aside the unanimous concern among the researcher is that UUS will reduce the surface environmental and social impacts. Swedish Royal Library, Le Grand Louvre museum of Paris are some remarkable projects that have played a pivotal role in utilizing underground space without changing the historically important surface structures.

Despite having long history of partial underground space utilization as a basement space, full underground space grew its importance only from 2000 A.D. in Japan. Now, Japan has approximately 1.6 million km of tunnel in the form of subway lines and ducts buried underground (Takayuki, 2016). China is another economically strong country having rapid urbanization rate of 10% to 50 % within a span of the last 60 years. So about 500 km of utility tunnels (that makes up 0.24 km per one thousand people) have been constructed in major cities of China in recent time which is more than other developed cities of the world that stands at 2 km per one thousand (Yang & Peng, 2016).

The Need for Underground Space in Nepal

According to Panthi (2006), water conveying tunnels, transport tunnels, mining, and food storage facilities are the aspects of development that can be explored with underground technology in Nepal. In present context traffic congestion, sound air pollution is the pressing problem with the growing urbanization around the world and Nepal is no different than that. Even if advanced public road transport is chosen it still occupies 3 to 12 times more space (Broere & Technology, 2016). Today car traffic occupies 30 to 90 times more space than the metro system.

Kathmandu has chosen a ring road to divert and segregate traffic, but the core problem is not eradicated yet. Though the surface space is considered safe and very approachable but space constraint is another challenge to overcome. For example, Table 1 shows the changes in built-up area in Kathmandu district from year 1990 to 2010 and a prediction for the year 2030. Similarly, Lalitpur area as shown in Figure 1 & Figure 2 show the reduction in open spaces in nearly two decades. These references can be correlated with the population growth as shown in Figure 3. The trend in population growth and limited space are very much upfront but the city planning and policy are nowhere to confront the issue. A similar situation was observed in big cities of Europe and Asia and they opted for an underground solution like double-deck tunnels in Paris and a large diameter of tunnels in Madrid (Broere & Technology, 2016). London underground cross rail project is another feat which is currently undergoing its construction having the busy London above it.

Table 1 Change in Built-up area from year 1990 to 2010 and prediction for 2030 of Kathmandu District (Wang et. al. 2020)

Year	Area (km^2)	% coverage
1990	65.09	14.83%
2010	99.24	22.61%
2030 (*Predicted*)	117.65	26.81%

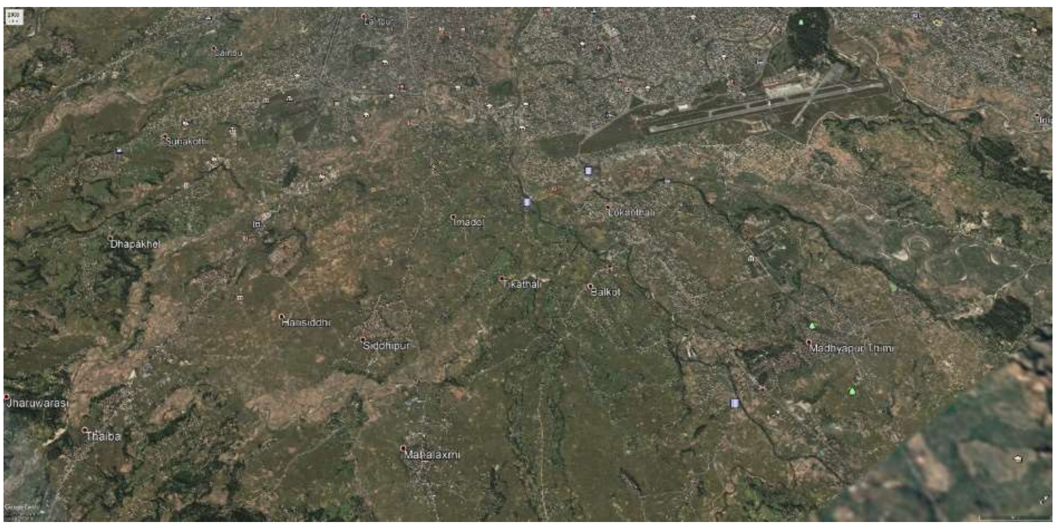


Figure 1: Google Earth Image of Lalitpur Area from 2003 (Google Earth Pro, 2020)

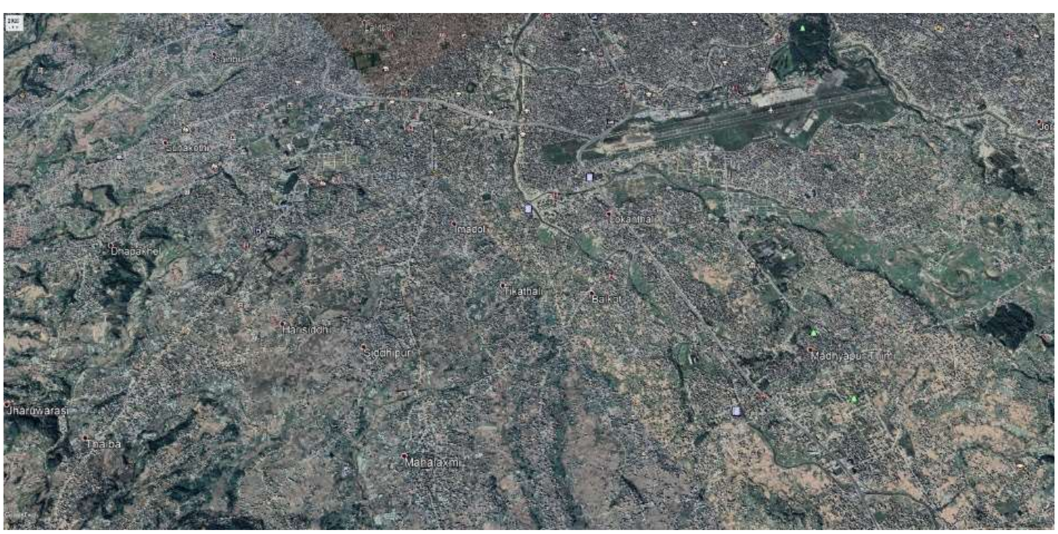


Figure 2: Google Earth Image of Lalitpur Area from 2020 (Google Earth Pro, 2020)

In the urban cities clear demarcation of underground rights is very important not only as to restrict the surface usage but to view underground as a natural resources that needs a proper management for a sustainable future(Vähäaho, 2014). Some modern cities like Singapore (30 m below ground Level), Tokyo (40 m below ground level), and Helsinki (6 m below ground level) has made a policy to address the subsurface usage limit which if looked in future perspective will clear out the ownership confusion (Stones & Heng, 2016).

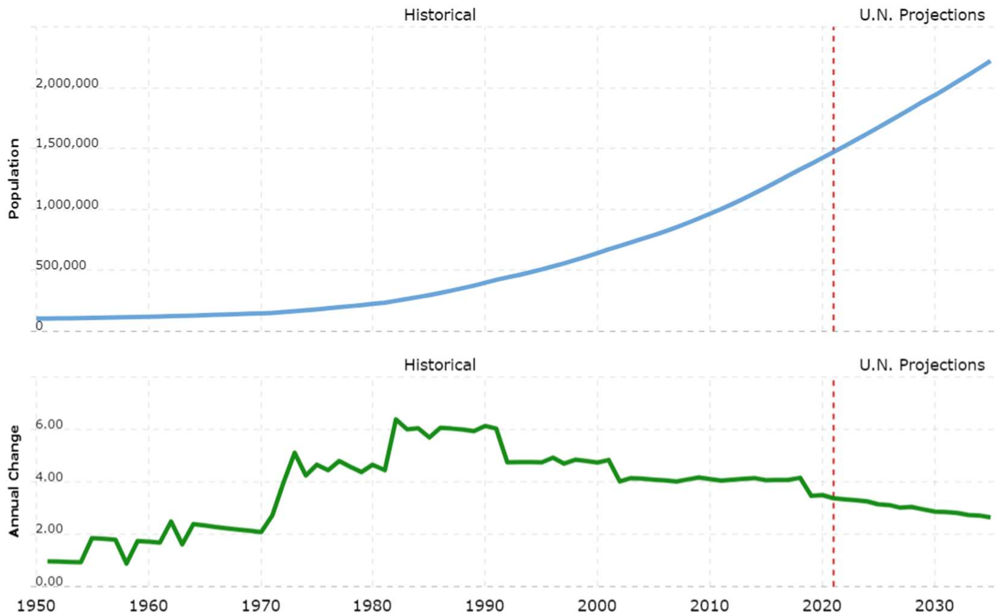
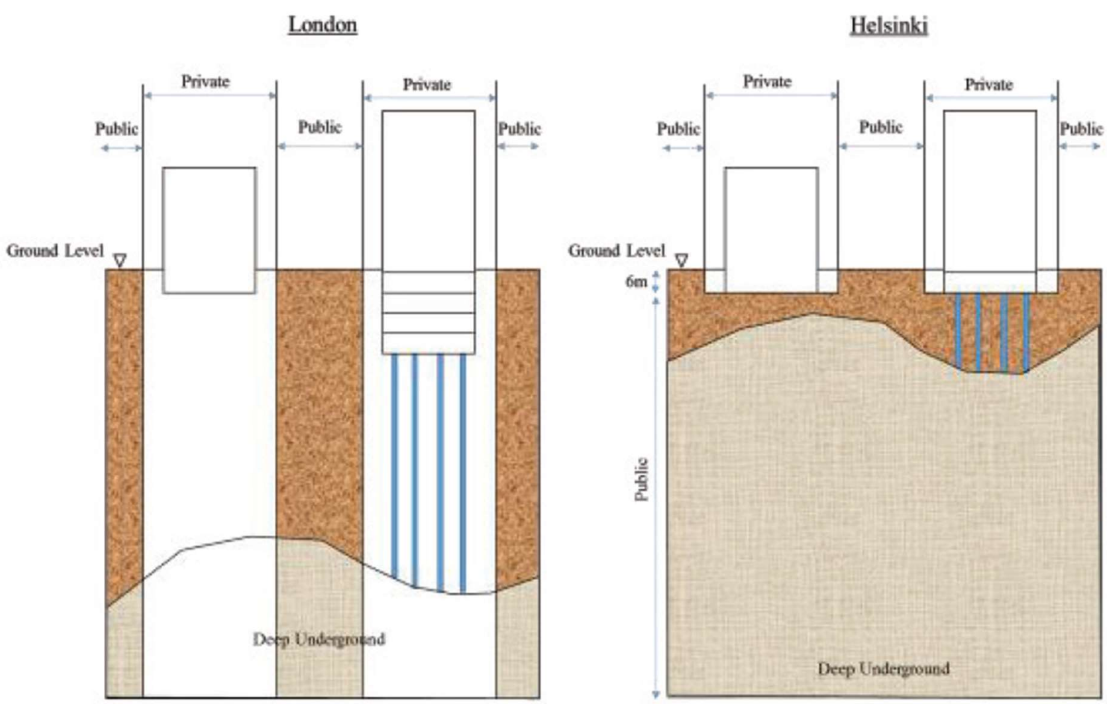


Figure 3: Population growth and forecasting as per UN Report on Kathmandu (LLC, 2021)

Preserving and planning of the underground space for better purpose and future need is very essential in early stage. Figure 4 addresses the way underground ownership can be segregated regardless of the surface structures.



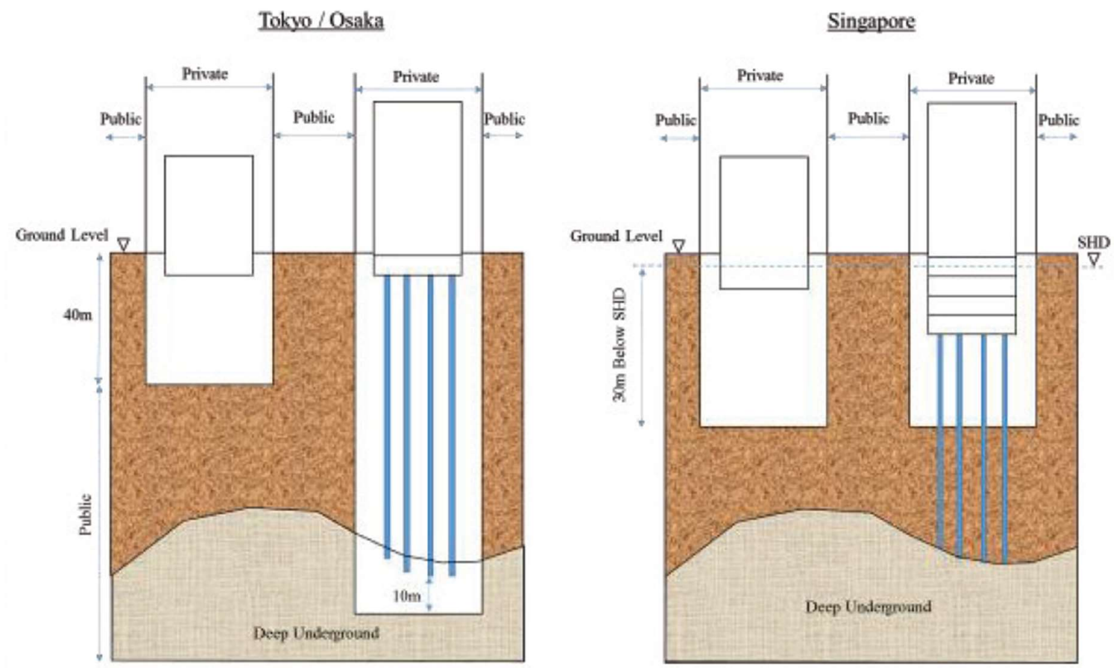


Figure 4: Major cities depicting their underground ownership conditions (Stones & Heng, 2016)

In context of Nepal, road access is not only the issue, the safe passage of wastewater (sewage), drinking water, and utility cable are always creating a havoc. Also, Storm water management in cities and slope failure in hilly roads is another recurrent challenges around the country. In such situations, Underground space has been an approachable methods around the world. Kuala Lumpur SMART tunnel project and Tokyo underground discharge channel are the modern method of storm water management that appears most effective in case of big cities and in the time of climate change(Ortiz, 2018; Patowary, 2013). It has to be acknowledged that proper ownership demarcation and underground space planning is the urgency in Nepal. In long run this will help all the designer to plan a sustainable space that will have full functionality and environmentally friendly habitation.

History of Tunneling and Current Situation in Nepal

In present scenario, approximately 267 km of tunnels have been completed for hydropower, irrigation, water supply, road, mining, and other purposes in Nepal of which about 90% is hydro tunnels (Shrestha & Sharma, 2019). Tunneling history in Nepal dates back 400 years when a 1.5 km long irrigation tunnel was excavated in Arghalli, Palpa. The first road tunnel was 239 m long constructed in Hetauda in 1927 A.D. Underground walkway in Ratna Park is an example of underground space utilization prevalent in Kathmandu.

Hydro tunneling started with the construction of Tinau HP (1966-1974) with a total length of 2400 m. The mode of excavation was primitive due to its location in the weak and fragile geology of the Siwalik region despite that project includes an underground powerhouse for the first time in Nepal (Svalheim, 2015). Similarly, Jhimruk Hydro -12MW (1989-1994) was the first one to introduce 280 m long inclined (45 degrees) pressure shaft in Nepal. Khimti-I HPP was designed with the longest headrace tunnel of length 8 km withstanding high head condition of 677 m (HPL, 2014-2019).

According to Panthi (2006), water conveying tunnels, transport tunnels, mining, and food storage facilities are the aspects of development that can be explored with underground technology in Nepal. From 1911, when the first hydropower was installed, to the present time, many technological shift has taken place; from surface channels to surface steel penstock, and underground waterways to fully underground powerhouse systems. Table 2 presents the hydropower situation as per the Department of Electricity Development (DOED), where most of the projects have full to partial underground space utilization. No doubt hydropower has been excelling in its field. As per construction practice in Nepal, drill and blast method is well practiced in all major underground works. Recently underground works in Bheri Babai project were completed by using TBM.

Table 2 Hydropower Situation in Nepal (DOED, 2021)

Description	Types	Installed Capacity (MW)	Number of Projects
Completed Projects	<1MW	1236.26	92
	>1MW	11.24	15
Application for Construction license	DOED*	1948.505	24
	IBN**	600	1
Construction License	>1 MW	9	3
	IBN	900	1
Application for survey license	<1MW	0.951	1
	>1MW	188.5	7
Survey License	<1 MW	10.74	15
	>1MW	15423.04	231
	IBN	1100	2

*Department of Electricity Authority ** Investment Board Nepal

Though road tunnels have been constructed in Hetauda, Kaligandaki, Marsyangdi, Upper Tamakoshi, and Melamchi projects but were not used as a public usage. At present, Nagdhunga-Naubise underground road tunnel (2.68 km) is considered as an option to conventional surface road option. The road tunnel is in construction phase and expected to be completed within 42 months. This project after completion is expected to reduce the traffic congestion and time of travel by on average 6.5 minutes from 25 minutes of the current route (JICA, 2015). Similarly not only waterway tunnels but underground caverns is also flourishing in the hydropower industry for accommodating powerhouse, surge chambers, settling basins and other utilities.

Melamchi diversion scheme is another important project that is designed to route 170 MLD of water directly from Melamchi River with a 26 km tunnel connecting with Kathmandu valley (Board, 2002-2016). Terai Madhes Fast Track includes a 6.5 km road tunnel which is also in the construction phase. Also, a total of 32.5 km of road tunnels are under the feasibility study phase and 149 km railway tunnels are under the pre-feasibility study phase located in various parts of the country (Shrestha & Sharma, 2019).

Challenges with Underground Space in Nepal

Nepal is a small country in South Asia which has a width ranging from 150 to 250 km north-south extending 890 km along east-west. In such a limited area, the varying altitude from 60 m in the south to 8848 m (Mt. Everest) in the north above sea level allows the diversity in the landscape rendering tunnel instabilities a common phenomenon. Panthi (2006) states that due to constant tectonic movement and intensive monsoon, the composition of Himalayan geology includes different kinds of discontinuities which creates instabilities more than anticipated. Also skill and experience in such geology is in learning phase. Due to above mentioned factors the discrepancy between predicted and actual instabilities was considerably large in completed projects of Nepal. The Author suggests that clear understanding of the geological phenomenon and availability of experienced manpower during project conception to design phase might reduce the chances of discrepancy.

Another most distressing concern in Nepal is the delay of the project. One of the reasons behind the most delayed projects is the limited level of investigation before the construction which ultimately results high level of uncertainty as shown in Figure 5.

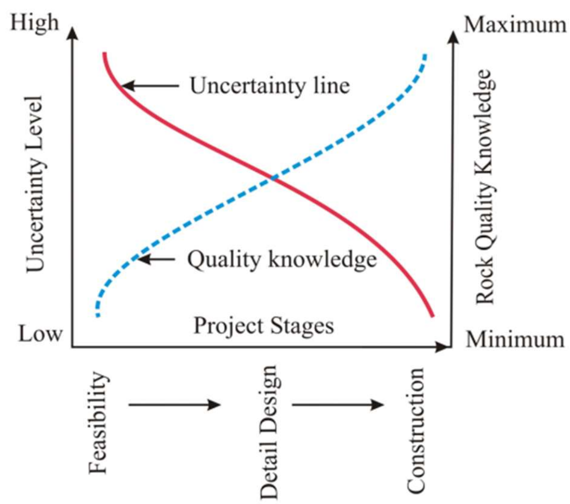


Figure 5: State of uncertainty and rock quality knowledge at different phase of project (Panthi, 2006)

Uncertainty and risk are time-dependent concerning rock quality knowledge (Panthi, 2017). The solution to such scenario is to increase the Rock quality knowledge at each phase of the project and have experienced personnel to interpret it rightly. For realistic prediction of uncertainties, Baecher and Christian (2005) has suggested to perform a stepwise investigation during the pre-construction which not only diagnoses the issue but also creates safe space for the project.

Conclusion

From the west to the thriving Asian nations, development and urbanization go hand in hand. Underground technology has proven a sensible option for sufficing the modernity and sustaining the cultural and historical element of the past. The reason could be that underground space is understood as natural resource that needs proper management and planning for better and sustainable future.

The purpose of this paper is to compare the worldly view in underground space utilization, practice in Nepal and future potential of it. Nepal, however, has long been practicing the technology, though mainly in hydro projects. With the current study and projects the scope of UUS is constantly expanding. In most cities in Nepal, urbanization is untamable but space utilization can be diversified creating environmentally viable and money for value projects. The development projects completed around the world had testified that. Still, there are some limitations regarding the identification of issues, advancement of geological knowledge and technological advancements but which will gain momentum with the number of projects itself. This is not an unsolvable aspect, but an open mind with sufficient research and finding can bolster the design even more.

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