ANALYSIS OF RISK IN TUNNEL BORING MACHINE ACTIVITIES IN TRANSPORTATION, EREACTION, AND ASSEMBLING

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Abstract

Tunnel construction in India is most expensive and high risk factors involved. This paper gives guidance to all those who have the job of preparing the report and overall scheme for the identification and management of risks in tunneling and underground projects. This paper provides owners and consultants with what ismodern-day industry practice for risk assessment, and describes the stages ofrisk management throughout the entire project from concept to start ofoperation. The purpose of this document “risk management" is the overall term which includes risk identification, risk assessment, risk analysis, risk elimination and risk mitigation and control.Then SPSS 20.0, a statistical analysis software package was used to conduct analysis based on the questionnaires. Risk in the tunnelling project cannot be eliminated completely; yet, suitable mitigation strategies can definitely be adopted to minimize these risks. This paper proposes an approach to risks in tunnel boring machine activities in Indian context. This shall help in achieving the project objectives in terms of avoiding cost overrun and time overrun of the project.

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Introduction

Tunnel development and construction in India have accelerated in the past few years. Over 1,500 km of tunnel length is currently under construction,almost equal to the achievement in the last 50 years.

Several landmark projects are currently under way. India's longest road tunnel, the 9 km Chenani-Nashri Tunnel, is under construction. Also, the 8.8 km Rohtang Tunnel is the world's longest road tunnel being built at an altitude of10,000 feet. The 43.5 km AliminetiMadhava Reddy Water Tunnel, which isbeing built in Andhra Pradesh, will be the world's longest TBM-driven tunnel without intermediate access. India's first underwater tunnel covering a length of520 metres is also being constructed as part of the Kolkata Metro project.

The scope and size of tunnel projects has increased over the years. The Indian Railways' biggest project, the Jammu-Udhampur-Baramulla railway line involves the development of a total tunnel length of 124 km at an investment ofRs 55 billion. The PulaSubbaiahVeligonda Water Tunnel Project, which requires an investment of Rs 73.5 billion, has been awarded in Andhra Pradesh. India's biggest urban water tunnel project, which will require an investment of Rs11.45 billion, is under way in Mumbai.

This pace of development is expected to increase in the next five years, ensuring that India remains one of the fastest growing tunnel markets in the world. There is a pipeline of at least 130 tunnel projects covering over 1,400 km for the next five years. These projects would entail a total investment of over Rs 1,370 billion. The maximum number of projects will be awarded as part ofhydropower projects. In terms of value, metro rail projects offer the biggest revenue opportunities.

However, to ensure high quality and timely construction, several risks and challenges need to be addressed. Geological surprises pose one of the biggest risks. Improvements in risk identification and assessment are required for tunneling projects. Also, the large-scale deployment of monitoring systemsneeds to be explored. Contractors also need to use innovative technologies to enhance productivity and ensure timely project delivery. Moreover, currentcontracting practices are old, with the allocation of risks being biased, and, therefore, need to be reviewed. There is also a greater room for the adoption ofinternational standards in tunnel design

and construction methods.

1.3 General- Tunnel

A **tunnel** is an underground passageway, completely enclosed except for openings for entrance and exit, commonly at each end. A tunnel may be for foot or vehicular road traffic, for rail traffic, or for a canal. The central portions of a rapid transit network are usually built in tunnels. Some tunnels are aqueducts to supply water for consumption or for hydroelectric stations or sewers. Utility tunnels are used for routing steam, chilled water, and electrical power. or telecommunication cables, as well asconnecting buildings for convenient passage of people and equipment.

1.4.2 Risk Management

Risk Management can therefore be defined as;

"The identification, analysis, assessment, control, and avoidance (minimization, or elimination) of risks. An organization may use risk assumption,risk avoidance, risk retention, risk transfer, or any other strategy (or combination of strategies) in proper management of future events."

1.5 Risk Management in Infrastructure Projects

Risk management is an integral part of majority of infrastructure projects. Many methodologies and guidance have been developed. Application of risk management in the construction industry has been motivated by the increasing complexity of the construction projects and by pressure for cost savings and for construction time reduction. Identification of risks in early design phase allowssignificant reduction of life-cycle costs through improvements of the design and planning and through appropriate treatment of the risk in the later phases. Generic guidance for the risk management process in construction projects can be found for example in Flanagan and Norman (1993), Edwards (1995), Wang and Roush (2000), Revere (2003), Institution of Civil Engineers et al. (2005), Smith et al. (2006) and Rozsypal (2008). A risk management section is also included in the broadly used manual of project management

(Project Management Institute, 2008). Some manuals have been developed specifically for the underground construction and tunnelling projects (Clayton, 2001; Eskesen et al., 2004; Staveren, 2006). In these manuals, a special attention is paid to the geotechnical risks, which play a crucial role in the underground construction.

2.0 LITERATURE REVIEW

Jorgen Kampmann, 2002

The paper gives guidance to all those who have the job of preparing the overall scheme for the identification and management of risks in tunneling and underground projects. The text provides owners and consultants with what is Modern-day industry practice of risk assessment, and describes the stages ofrisk management throughout the entire project from concept to start ofoperation.

Hazard identification

The process of identification may rely upon;

i) a review of world-wide operational experience of similar projects drawn from the literature with written submissions from partner companies,

ii) ii) the study of generic guidance on hazards associated with the type of work being undertaken, and iii) discussions with qualified and experienced staff from the project team and other organizations around the world. It is important to identify the potential hazards in a structured process. A suggestion for grouping is proposed below

General Hazards

1. Contractual disputes
2. Insolvency and institutional problems,
3. Authorities interference,
4. Third party interference,
5. Labour disputes

Specific Hazards

6. Accidental occurrences,
7. Unforeseen adverse conditions,
8. Inadequate designs, specifications and programmes,
9. Failure of major equipment, and
10. Substandard, slow or out of tolerance works.

Frequency of occurrence			
Frequency class	Interval	Central value	Descriptive frequency class
5	>0.3	1	Very likely
4	0.03 to 0.3	0.1	likely
3	0.003 to 0.03	0.01	Occasional
2	0.0003 to 0.003	0.001	Unlikely
1	<0.0003	- 0.0001	Very unlikely

Table-2 Frequency of Occurrence (In the Construction Period).

The central value represents the logarithmic mean value of the given interval.

	Consequence				
Frequency	**Disastrous**	**Severe**	**Serious**	**Considerable**	**Insignificant**
Very likely	Unacceptable	Unacceptable	Unacceptable	Unwanted	Unwanted
Likely	Unacceptable	Unacceptable	Unwanted	Unwanted	Acceptable
Occasional	Unacceptable	Unwanted	Unwanted	Acceptable	Acceptable
Unlikely	Unwanted	Unwanted	Acceptable	Acceptable	Negligible
Very unlikely	Unwanted	Acceptable*	Acceptable	Negligible	Negligible

Table-3 Risk Matrix (Example)

The purpose of this document "risk management" is the overall term which includes risk identification, risk assessment, risk analysis, risk elimination and risk mitigation and control.

3.0 Risk Identification

Determining what risks or hazards exist or are anticipated, their characteristics, remoteness in time, duration period, and outcomes. Risk identification activities establish what risks are of concern. These activitiesinclude:

- Identifying risk/uncertainty sources and drivers,
- Transforming uncertainty into risk,
- Quantifying risk,
- Identifying probability, and
- Establishing the priority of risk items.

Risk Analysis, Quantification and Prioritization

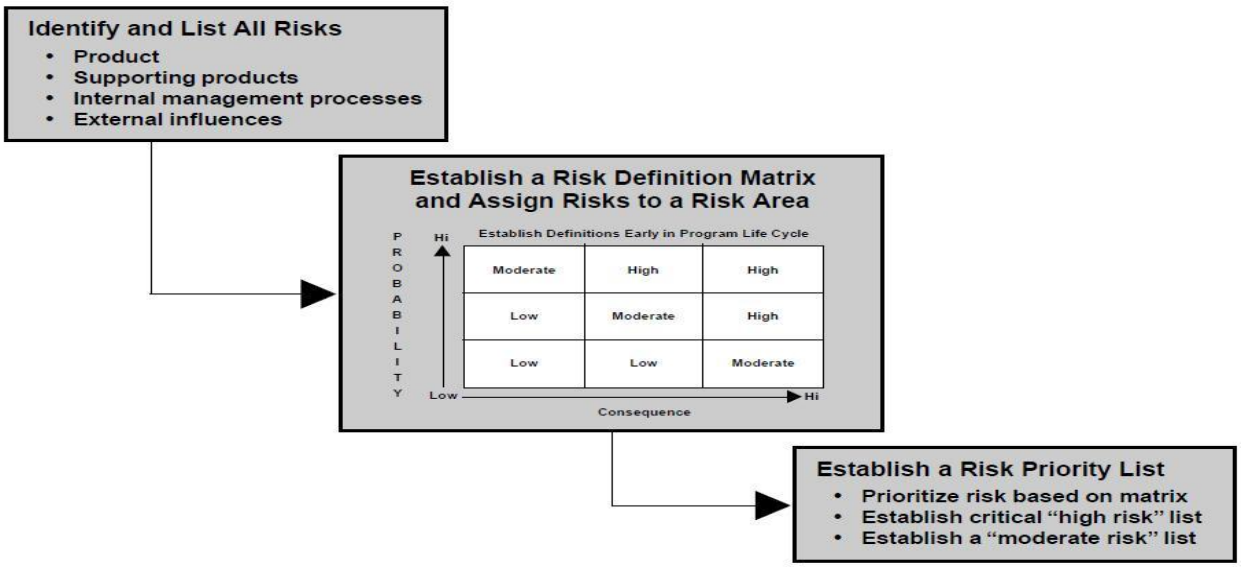

Figure: 6 Risk analysis activities

METHODOLOGY

4.1 Risk Identification and Classification

The proposed approach in this paper considers risk as a future event which has an adverse effect on the transportation, erection and assembly oftunnel boring machine in India. As no previous records of the different types ofrisks are not available in India, authors had to interview a team of tunneling professionals and key personnel working at respective

CMRL.

The proposed approach has three stages as below:

- Risk identification, categorization and classification
- Risk prioritization

4.1.1 General Operation Inside Tunnel

The risks have a considerable impact on the General operation inside tunnel especially in India

- Inadequate oxygen level or presence of poisonous gases
- Fall on height / object fall from height
- Electrical power failure / lights
- Fire accidents
- Damage via 3rd party construction
- Electrical accidents / personals
- Injury from erector operation
- Smoke without fire
- Over time working of equipment
- Over time working of labor

4.1.2 Transportation of TBM Parts

The major disadvantage of TBM are expensive to construct, and can be difficult to transport to site, in heavily urbanized cities, like Chennai. The risk are consider by Indian road conditions and factors.

- Accident to the vehicle.
- Damage to the road side structures
- Damage to the vehicle by roadside structures.
- Damage to the Tyres. Collapse of vehicle
- Damage to the Street lights or Electric lines
- Damage to the Tyres. Collapse of vehicle
- Damage to the Street lights or Electric lines.
- Damage to the utilities.

- Placing / sitting of tbm parts inthe truck
- Truck condition (tyres, bearings, break, lights, etc.,)
- Truck driver condition (alcohol consumption, experience, etc.,)

4.1.3 Lifting TBM Parts from Trailer & Lowering in to Leveled Ground

This risk is considered of erection of TBM parts from vehicle to the leveled ground by crane operation and

- Fall of suspended load while crane is on operation.
- Swing area of crane when crane is in use
- Snapping of wire (cut)
- Failure of boom
- Malfunctioning of crane (overloading and or working beyond limits)
- Misunderstanding between operator and signal man (Lack ofcommunication),
- Malfunctioning of crane (overloading and or working beyond limits)
- Misunderstanding between operator and signal man (Lack ofcommunication)
- Fall& Breaking ofTBM Parts
- Inclement weather, rain, sun, storm
- Hydraulic failure
- Operator mishandling

4.1.4 Assembly of Main Drive

Main drive is the first unit in TBM and its having high power motors, hydraulic units, sensors, and control unit. This risk are consider while assembly of the main drive of the TBM in site. This is first unit in TBM.

- Hitting of erector on otherTBM parts and personnel
- Fixing/ damage of erector while assembly
- Hitting of screw conveyor on personnel's and other parts of TBM
- Improper positioning and damage of CCTV cameras, sensors, sensor cables
- Improper connection of power, pressure, and hydraulic cables
- Failure and damage of connection of sensor, and sensor cable into control unit
- Failure and damage of CCTV camera and camera cables

- Damage others assembly and connection to control unit

4.1.5 Assembly of Rolling Stock

The rolling stock is the rotatory part of the TBM which is assembled in front of the main drive unit. The risk is consider while assembling of rolling stock with main drive unit

- Adjustments of height between rolling stock and main drive
- Hitting of rolling stock to main drive
- Personnel injured by rolling stock and main drive
- Derailments during or after assembly
- Reduced loco driver visibility on EPB
- Accidental de-coupling of rolling stock.
- Driver& workers strikes head against tunnel objects
- Train runway under electrical power
- Excessive Speed of rolling stock
- Breakage and failure of other parts

FINAL CONSEQUENCES TUNNELING RISK.sav [DataSet1] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

	Name	Type	Width	Decimals	Label	Values
1	GRLQ1	Numeric	8	0	Inadequate space for	{0, NIL}...
2	GRLQ2	Numeric	8	0	Fall on height / object fall from height	{0, NIL}...
3	GRLQ3	Numeric	8	0	Electrical power failure/ lights	{0, NIL}...
4	GRLQ4	Numeric	8	0	Fire accidents	{0, NIL}...
5	GRLQ5	Numeric	8	0	Damage via 3rd party construction	{0, NIL}...
6	GRLQ6	Numeric	8	0	Electrical accidents / personals	{0, NIL}...
7	GRLQ7	Numeric	8	0	Injury from erector operation	{0, NIL}...
8	GRLQ8	Numeric	8	0	Smoke without fire	{0, NIL}...
9	GRLQ9	Numeric	8	0	Over time working of equipment	{0, NIL}...
10	GRLQ10	Numeric	8	0	Over time working of labor	{0, NIL}...
11	SHIPQ11	Numeric	8	0	Accident to vehicle	{0, NIL}...
12	SHIPQ12	Numeric	8	0	Topple of trailer if travelled in uneven or unleveled road	{0, NIL}...
13	SHIPQ13	Numeric	8	0	Break down of truck	{0, NIL}...
14	SHIPQ14	Numeric	8	0	Reversing of vehicles	{0, NIL}...
15	SHIPQ15	Numeric	8	0	Damage to the road side structures	{0, NIL}...
16	SHIPQ16	Numeric	8	0	Damage cable, vehicle and TBM by roadside structures	{0, NIL}...
17	SHIPQ17	Numeric	8	0	Damage to the Tyres. Collapse of vehicle	{0, NIL}...
18	SHIPQ18	Numeric	8	0	Damage to the Street lights or Electric lines.	{0, NIL}...
19	SHIPQ19	Numeric	8	0	Damage to the utilities.	{0, NIL}...
20	SHIPQ20	Numeric	8	0	Placing/ Sitting of TBM parts in trucks	{0, NIL}...
21	SHIPQ21	Numeric	8	0	Truck condition (tyres , bearings, break, lights, etc.,)	{0, NIL}...
22	SHIPQ22	Numeric	8	0	Truck driver condition	{0, NIL}...
23	CRANEQ23	Numeric	8	0	Slipping of wire	{0, NIL}...
24	CRANEQ24	Numeric	8	0	Sitting of crane	{0, NIL}...

RESULTS AND DISCUSSIONS

Statistical analysis is done using SPSS which is a comprehensive and flexible statistical analysis and data management solution. SPSS can take data from almost any type of file and use them to generate tabulated reports, charts, and plots of distributions and trends, descriptive statistics, and conduct complex statistical analyses. SPSS is available from several platforms; Windows,Macintosh, and the UNIX systems. SPSS (Statistical Package for the Social Sciences) is a computer program used for survey authoring and deployment, data mining, text analytics, statistical analysis. Statistics included in the base software such as in descriptive statistics methods of cross tabulation, frequencies, exploring, and descriptive ratio statistics can be included. In the bi variant statistics, such as means, tests, correlation, non-parametric tests can be performed.

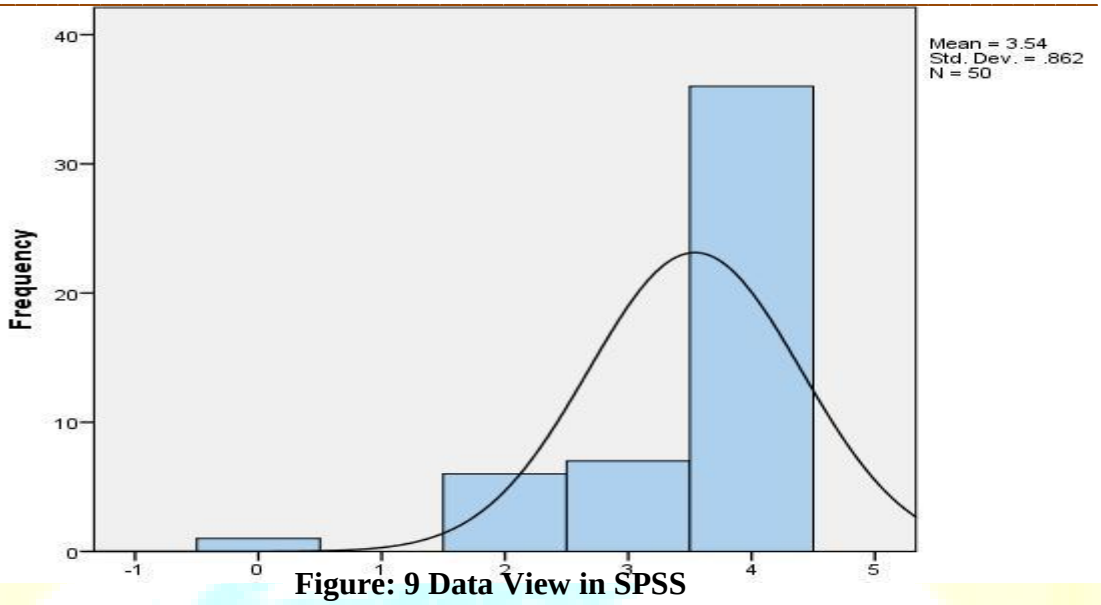

Figure: 9 Data View in SPSS

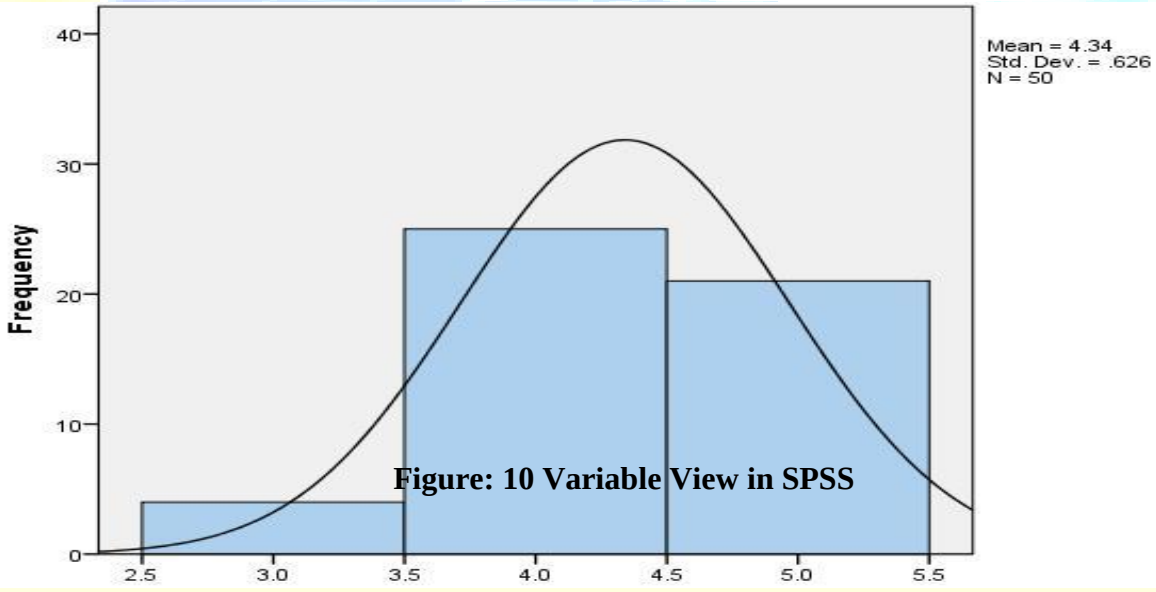

Figure: 10 Variable View in SPSS

Figure: 21 Bar Chart for Contact of power cables.

The graphs generated using SPSS are shown above while, Mean ispresented in y-axis and risks in x-axis. Manual ranking of risks purely based on frequency is not possible as both factors i.e., probability and consequence have to be considered, hence SPSS is used high probability and high consequence risks show up as high mean and high standard deviation risks. Higher mean and probability risks are arranged in ascending order as below:

SL. NO	RISK	Mean	
1.	Inadequate oxygen supply and poisonous gas	3.54	4.70
2	Accident of vehicle.	3.62	4.44
3	Damage to the vehicle and TBM by roadside Structures.	3.18	3.92
4	Damage to the Street lights or Electric lines and Other utilities.	3.96	3.34
5	Operator mishandling	3.94	3.96
6	Malfunction of hydraulic unit and crane	3.18	3.94
7	Slipping of wire or cut of wire.	3.12	3.62
8	Improper positioning of sensor, sensor cable, and CCTV camera	4.10	3.62
9	Contact of power cables	4.14	4.34
10	Damage of motors (rolling stock, main drive, Generators, etc.)	4.42	4.50

Table: 5 Top Risk Factors.

Risk	Accident of vehicle
	Damage to the vehicle and TBM by roadside structures.
	Damage to the Street lights or Electric lines and other Utilities.
Potential	Damage of TBM parts, vehicle, roadside structure, and Other utilities. Personal injuries, delay of project starts, Cost overrun
Hazards Recommendations for mitigation strategies	□ Truck should drive at the speed of 10– 30 kmph. □ Transport all trucks and parts at midnight only12:00- 4:00 am □ Driversshould be well experienced and skill Persons. □ Drivers shouldnot consume any drugs and Liquor. □ Escort the vehicle in front of trucks while transporting the bigger parts. □ Get proper clearance (NOC) from Chennai citytraffic police department and remove traffic barriers if needed. □ Get proper clearance (NOC) from Chennai Corporation and public work department (PWD) and remove any road structure and other utilities ifneeded. □ Power lines, advertisement boards, traffic signals, and other public utilities are removing and cleartemporarily of the obstacle level in the road. □ Barred other heavy vehicle and traffic by traffic police department.

Risk	Operator mishandling
Potential hazards	Malfunction of hydraulic unit and crane
	Slipping of wire or cut of wire.
	Damage of TBM parts, vehicle, Personnel injuries, delayof project starts, cost overrun

Recommendations for mitigation strategies	□ Operator should be well experienced and skill person. □ Communication device like intercom, walk talkyand other equipment are in good quality and proper condition □ Signal man should have well experience, skill person and good technical communication between operator and signal man. □ High quality and high strength steal wire should be used and completely verified before operation □ Hydraulic motors, cables, and valves are checked before operation. □ Completely avoid overloading. Operate appropriate load level of the crane. □ Barricade should be fixed in all the swing direction of crane

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