Risk Management in Construction of Cross Passage With Live Tunneling

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Abstract- *In this paper, construction of cross passage of urban metro is discussed using a case study of CMRL project. Emphasize is given on cross passage works along with live tunneling. The methodology and value engineering has been illustrated to elaborate the benefits of the same. Approach adopted to address the various problems encountered during execution is reported in project.*

Keywords- Cross Passage, risk evaluation, Mulazor

I. INTRODUCTION

Transportation plays a vital role in development of a nation. One of current scenario in India transportation is Metro Rails construction through the lengths and breaths of major cities which includes Mumbai, Delhi, Chennai, Bangalore and recently it's been sanctioned in Pune.

Construction of Metro Rail requires huge funds due to requirement of machineries, expert consultants, and number of man power. This may differ according to the type of Metro line which can underground or overhead. So it is need to highlight most efficient technique of construction without affecting its quality.

PROJECT BACKGROUND

The population of Chennai in 1639 was 40000 and today the city is estimated to have a population of 7.5 million, which gives a population density of about 6482 per sq. km. The city, with its present population generates about 11 million trips in a day, with about 6million vehicular trips. The ever growing vehicular and passenger demands coupled with constraints on capacity augmentation of the existing network have resulted in chaotic condition during peak hours of the day.

A number of transportation studies were carried out in the past for Chennai Metropolitan Development Authority (CMDA). These studies discussed travel pattern, network characteristics and the degree of traffic saturation on the existing roads in the Study Area. The proposed high capacity, high frequency metro will not only be a cheaper mode of transport but also provide for a safer, reliable and better customer service. A feasibility study was carried out in 2003 to select and priorities the corridors for Chennai metro. Based on detailed traffic surveys seven corridors were identified.

- Corridors:

The portions of Corridor-1 with a length of 14.3 kms. from Washermanpet to Saidapet, and Corridor-2 with a length of 9.7 kms. from Chennai Central to Anna Nagar 2nd Avenue will be underground and the remainder elevated.

- Corridor-1:

Washermenpet – Manadi – High court – Chennai central – Government estate – LIC – Thousang lights – AG DMS – Teynampet – Nandhanam – Saidapet - Chennai Airport

- Corridor-2:

Chennai central – Egmore – Nehrupark – Kilpauk – Pahiyappa's college – shenoy nagar – Annanagar East – Anna nagar tower – Thirumangalam

Benefits of Metro to commuters

1. Time saving for commuters
2. Reliable and safe journey
3. Reduction in atmospheric pollution
4. Reduction in accident
5. Reduced fuel consumption
6. Reduced vehicle operating costs
7. Increase in the average speed of road vehicles
8. Improvement in the quality of life
9. More attractive city for economic investment and growth

II. OBJECTIVE

- Brief study of Methodology adopted for construction of Cross Passages.

- In depth analysis of Construction of Cross Passages during Live Tunneling.
- To establish pro-active approach in identifying, evaluating and mitigating risks associated with execution of project.

III. REVIEW OF LITERATURE

R.G. Saini, Ishaan Uniyal (2016): -

In this paper, work for the cross-passage for CC27 of Delhi Metro by L&T-SUCG JV commenced after the completion of the twin tunnel on account of ease and efficiency. Method employed for construction of the cross-passage was excavation by heading and benching. The paper also reports a solution adopted for mitigation of a major problem of water-logging encountered during the construction. Approach adopted to address the problem was use of pressure grout and pumping out excess water. Efficacy of the procedure utilized and applicable conditions for same along with possible contributing factors have been also indicated.

Xiangdong Hu (2011): -

This thesis summarizes cross passage construction methods for soft ground conditions in China, in which the most successful and popular one, mining method with ground improved by artificial ground freezing and its risk prevention and safety protection measures, are introduced in detail.

Tsai, Y.Y. (2010): -

In this paper, design and construction of cross passage of urban metro are discussed using a case history from a contract at south end of Qutab Minar Line of the Delhi metro project. In order to start to build permanent structural works in TBM driven shafts as early as possible, construction activities of cross passages should be isolated from TBM shafts. Vertical shafts for cross passages were thus installed between the two main running tunnels from ground surface level to increase workable areas as well as to transport excavated spoil. Details of design and construction of the cross passage will be reported in this paper.

According to all researches mentioned above, in each cases the construction of Cross Passage begins after the completion of the transit tunnels which intern requires separate funds apart from which is required for the main tunnel construction with respect to time, machineries and manpower.

Based on above discussion, for our study it is necessary to analyze the practical problems encountered during the construction of Cross Passages and the techniques that were adopted for mitigating those problems.

IV. METHODOLOGY

- Site Visit to CMRL Project; wherein site activities, drawings, project feasibility study was done.
- Site Management assigned to monitor ongoing activities mainly cross passage works.
- In-depth analysis of cross passage with live tunnelling and conventional method was too carried out.
- After analysis Value Engineering conceptualize by preparing extra cost and duration analysis.
- Lastly, Risk Analysis was performed to identify the Risk Factor for the project.

V. METHOD OF CONSTRUCTION (CONVENTIONAL vs INNOVATIVE)

CONVENTIONAL METHOD:

Construction of the cross-passages is taken up only after completion of the tunnels on account of ease of working and efficiency.

Following steps were followed for construction of cross passage.

(i) Marking up of the survey lines (for excavation purpose) with the help of total station.
(ii) Temporary structural ring for supporting the tunnel ring to be installed for the tunnel support.
(iii) Packing of the ring girder with wooden wedges so as to fill the void spaces between the tunnel segment and the ring members thereby increasing the contact area and thus the overall strength of the system.
(iv) The cut-out portion of the ring with steel lintel beams to be installed in two segment cut-outs using core cutting machine to be done at each cross passage entry sections.
    a) In the upper section as " Top lintel".
    b) In the bottom section as "Bottom lintel"
(v) The opening area segment cut to be removed. Next in the course of excavation, reinforcement steel lattice girder as per the design considerations, is placed inside the cross passage to support the excavated strata, where in the load gets transferred by 'arch effect'.
(vi) To ensure the stable and safe cross passage construction and minimize ground movements within

the surrounding area due to exposure of unsupported ground, a suitable tunnel support has to be installed as soon as possible. Lattice girders in conjunction with Shotcrete are achieving an excellent level of tunnel support and are therefore commonly used in tunnelling. These lattice girder rings are having following advantages:

a) Reasonable easy and accurate in dimensions to manufacture.
b) Due to the reduced weight (compared to full steel rings) easy to transport, store and handle in the tunnel.
c) Accurate template guide for tunnel profile during excavation.
d) Accurate guide for required Shotcrete thickness for the Shotcrete application.
e) Fully embedding of the steel structure in the lining by Shotcrete coating all around the steel structure done.
f) Fast ring installation during construction process.
g) Easy adoption to ground condition due to flexibility in ring spacing and ring assembly sequence

INNOVATIVE APPROACH:

Unlike conventional method construction of the cross-passages is taken up parallel to the tunnel mining on account of ease of working and efficiency with "time saving".

In this innovative approach of construction the below mentioned areas are to be modified compared to the conventional method

a) Track Shifting
b) Working Platform
c) Usage of Mini Excavator for faster excavation
d) Modified Concrete Transport & Pouring method.

a) Track Shifting:

At Cross passage section the alignment of track line changed compared to normal tunnel alignment section. For the location where the rail line is to be side shifted, special size sleepers of 3.24m length with two legged is used to get more width. The two legged sleeper are used to provide more stability to eccentric rail track.

b) Working Platform:

The working platform with both side ramp to accommodate the needed equipment's & construction materials (pumps, agitators, tanks, grouting, shotcreting, excavated materials & mini excavator etc.) to be installed in the tunnel cross passage section.

c) Usage of Mini excavator:

Mini excavator used for faster excavation and also for utilizing the time gap of mining rolling stock.

It helps in faster muck disposal, thus accommodating between ring building & mining.

JS 30 features: Operating Weight: 2870kg,
Net Engine Power: 18.4kW (24.7 hp)
Maximum Bucket Capacity0.076 cum
TMX 20 features: Operating Weight: 2200kg,

Net Engine Power: 28 hp
Maximum Bucket Capacity0.12 cum

d) Modified Concrete Transport & pouring method:

Modification & Implementation of concrete transportation & pouring method during shut down time of mining. During down time of TBM mining the concreting of cross passages done by introducing concrete re-mixer (Mulazor). The dimension of re-mixer selected so that it can be accommodated within the available tunnel rolling stock space & ease in concrete delivery to concrete pump.

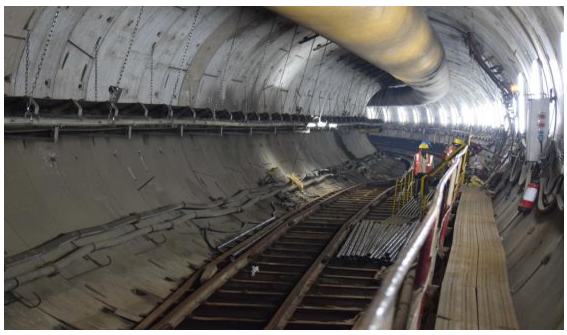

Photo 1: Track Shifting

Photo 2: Mini Excavator working over Platform

Photo 3: Mulazor

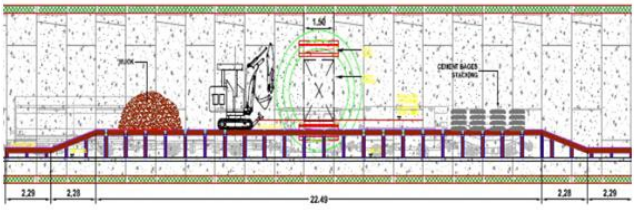

Photo 4: Equipment over Platform with Muck & Material Stacking

VI. RISK MANAGEMENT

- The main purpose of this procedure is to establish a proactive approach in identifying, evaluating and mitigating risks associated with selection of tender up to execution of project.
- The scope of this procedure starts once Proposal Manager handed over the awarded project to Project Manager for execution. This procedure involves systematic quantification and managing all risks and opportunities that can affect successful execution of projects. Mitigation measures as recommended by management during review to be duly implemented for project completion. Any new risk identified during project execution shall be analysed and quantified with mitigation measures.

RISK EVALUATION

- An evaluation of the risk helps in understanding the nature and quantum of risk and its likely impact and possible mitigation measures. The consequences arising from occurrence of risks can be either economic or non-economic and determine the severity of a risk.
- Clear and well defined risk acceptance thresholds are identified in order to determine the level of risk that can be tolerated. Risk acceptance thresholds are based on defined scales for likelihood and consequences, Risks are then assessed and classified against the predefined parameters s under:

Table No. 01: Risk Ranking Matrix

Risk Ranking Matrix					
Probability 5	5				
4	4	5		RMAP Optional	
3	3	4	5		
2	2	3	4	5	
1	1	2	3	4	5
	1	2	3	4	5
			Impact		

Table No. 02: Impact Assessment

Impact Assessment		
Rank	**Qualitative**	**Impact**
5	Crisis	Catastrophic
4	Critical	High
3	Significant	Moderate
2	Marginal	Low
1	Negligible	Insignificant

Table No. 03: Probability Assessment

Probability Assessment		
Rank	**%**	**Qualitative**
5	> 80%	Almost Certain
4	60 - 80%	Likely
3	30 - 60%	Possible
2	10 - 30%	Unlikely
1	< 10%	Rare

Table No. 04: Risk Assessment Matrix (5 x 5)

	IMPACT					
PROBABILITY		Catastrophic 5	High 4	Moderate 3	Low 2	Insignificant 1
	Almost Certain 5					
	Likely 4		>5.1 >5.3 >6.1 >7.2 >10.2	>3.4 >4.1		
	Possible 3		>6.2	>1.1 >1.2 >3.1 >3.2 >5.2 >7.1 >8.3 >9.1 >11.1	>4.2 >8.1 >10.1	
	Unlikely 2		>8.4	>9.2	>1.3 >8.2 >11.2	>6.3
	Rare 1					>2.1 >3.3 >4.3

- With above analysis the project risk factor is 2.78 which well below 3 having moderate impact on the project, so there is higher chances of accepting the project is possible.

VII. CONCLUSION

- Construction of cross passages is a tedious and costlier affair. Hence the construction has to be preciously planned and executed. Construction along with Live tunneling is a better option, but due care needs to be taken while executing.
- Live tunneling cross passage excavation helps in transshipment of material and manpower with the help of locomotive. Thus reducing in construction time as well as lesser cost.
- Also, requisite manpower can be shared during tunneling activities. Otherwise the extended stay is required.
- Generally, all over the India it has been notice the cross passage works delay the site by 03-06 months after tunneling. Hence this technique will be helpful in reducing the extension of time.

APPENDIX

R/O NO	RISK/OPPORTUNITY EVENT	RISK/OPPORTUNITY DESCRIPTION	MITIGATION MEASURES	RESPONSE STRATEGY	RESPONSIBILITY	PROBABILITY	IMPACT	RANKING	REMARKS
A	***PRETENDERING***								
1	COUNTRY RISK								
1.1	Political stability	**Cause:** CM's Demise led to instability in Tamil Nadu. **Risk:** Delay in government approvals. **Effect:** Cost Overrun	Proper documentation of events, notifying client and follow-up of the same.	Retain-Unpriced	Contract Manager & Project Manager (Follow-up)	Possible	Moderate	3	Shall be helpful in arbitration.
1.2	Economic stability	**Cause:** Fund crunch. **Risk:** Delay in government approvals. **Effect:** Cash inflow	Being funded by JICA, economic stability risk is low. Still external funding modes to be identified and sorted out.	Retain-Priced	Accounts & MIS	Rare	High	2.5	
1.3	Currency exchange rate and banking	**Cause:** Market variation **Risk:** Increase in cost **Effect:** Cash inflow & profit margin	Last 5 years foreign exchange to be studied and accordingly rate to be incorporated.	Retain-Priced	Accounts & MIS	Possible	Insignificant	2	
2	CLIENT RISK								
2.1	Client default	**Risk:** Project Terminaton. **Effect:** Investment return.	Cost Provision to be considered.	Avoidance	HO & Project Manager	Rare	Insignificant	1	
B	***TENDERING***								
3	CONTRACT CONDITION								
3.1	Liquidated damages	**Cause**: Maximum LD limited to 10**%** of the CV **Risk:** Delay in achieveing Completion of the respective Keydates **Effect:** Cost Overrun	Required resources in the form of Manpower & Equipments has been priced.	Retain-Priced	CPMG	Unlikely	Moderate	2.5	
3.2	Variation clause	**Cause:** Any Variation beyond the scope of works from the tender requirement shall be paid as per the rates as provided in the contract.	As this is a Design build and Turnley Project, Variartion if any shall be quantified only during the course of the project	Retain-Unpriced	Project Manager	Possible	Moderate	3	

3.3	Defect liability period	**Cause: 24 months** calculated from the date of issuance of Taking Over Cerficate **Risk:** We may underestimate the duration. **Effect:** Cost Overrun	All works will be carried out as per Specification & Quality in turn no repair works forseen during Defect Liability Period.	Retain-Unpriced	Project Manager	Rare	Insignific ant	1	
3.4	Arbitration	**Cause:** Arbitration will be in accordance with Indian **Arbitration & Conciliation Act 1996 as ammended from time to time.** Committee of Arbitrators shall be appointed composed of one Arbitrator to be by the Contractor, one to be by the Employer and the third Arbitrator, who will act as a chairman but not as umpire**,** to be chosen jointly by the two nominees. The decision of majority of Arbitrators shall be final and binding on both parties. **Risk:** Nil **Effect:** Absence will have client upper edge on resoving dispute & Claims	Timely notification of happening of the event at site which was affected due to delay by the Employer with all contemporaneous records shall be in advantage of the Contractor to win in Arbitration	Retain-Unpriced	Project Manager	Likely	Moderate	3.5	
4	FINANCIAL RISK								
4.1	Progress Payment Time	**Cause:** Running Account Bill **Monthly** Payment of the Contractor's on account bill shall be made by the Employer **within 56 days from the date of submission of the bill** Interest on delayed payment - **annual rate three percentage points above the discount rate of Central bank in the Country of the currrency of payment** **Risk:** Negative Cash Flow **Effect:** Inclusion of interest cost will increase the cost	Payment period is fair. Cashflow impact to be included in the cost.	Retain-Priced	Tender Manager	Likely	Moderate	3.5	
4.2	Retention money	**Cause:** Cash retention @ 2.5% of RA bill, **Risk:** We may underestimate the bid **Effect:** Will have impact on Cashflow	Nil	Retain-Priced	Tender Manager	Possible	Low	2.5	Estim ated cost in tender Price of Rs. 0 cr.

4.3	Taxes and duties	**Cause:** The price basis shall include all taxes and duties, etc. during contract period. Sales Tax, local taxes and other levies. **Service Tax is exempted and excise duty is reimbursable** **Risk:** We may underestimate the bid **Effect:** Cost Overrun	Tax component to be discussed, computed & included in cost in consultation with Taxation Dept.	Retain-Priced	Tender Manager	Rare	Insicnific ant	1	Estim ated cost in tender Price of Rs. 0 cr.
5	MATERIAL RISK								
5.1	Specifications	**Cause:** Material specifications are normal, crisis in getting River sand. **Risk:** Limited suppliers available who can supply river sand. **Effect**: Delay in Concrete Pouring.	Trial with Manufactured sand has been made and found meeting the specification requirements.	Avoidance	Quality Manager	Likely	High	4	
5.2	Availability	**Cause:** Crisis in getting River sand. **Risk:** Possibility of increase in cost of Sand due to cartelisation. **Effect:** Effect on Cost Overrun	Trial with Manufactured sand has been made and found meeting the specification requirements.	Retain-Priced	Quality Manager	Possible	Moderate	3	
5.3	Monopoly	**Cause:** Quarry owner carteling **Risk:** Increase in Quarry lease rates **Effect**: Effect on Cost Overrun	Quotations received from all Msand suppliers. No other development in the area except this project.	Avoidance	Tender Manager	Likely	High	4	
6	LABOUR RISK								
6.1	Availability of labour	**Cause:** Approx 2500 manpower required **Risk:** Non availablity of skilled manpower may cause cost & time overrun. **Effect: E**ffect on Time & cost overrun	Mix of own & Local labour contractor to be deployed.	Avoidance	Project Manager	Likely	High	4	
6.2	Union/influence	**Cause:** No Local labour union exists**Risk: Effect**: May cause cost overun & schedule slippage	Cost Provision for Union Influence considered in Business Expenses	Avoidance	Project Manager	Possible	High	3.5	
6.3	Labour laws	**Cause:** Labour Laws **Risk:** No Risk Forseen **Effect:** No effect on cost overrun	All provisions as per local labour law shall be taken in cost.	Retain-Priced	Project Manager	Unlikely	Insicnific ant	1.5	
7	EQUIPMENT RISK								
7.1	Availability of equipment	**Cause:** Sophisticated equipments & technology required. **Risk:** Work delay. **Effect:** Project delay &cost overrun.	CAPEX sholud include specialise machiniers. Not to invest on localised equipments. Development of strong vendor base	Retain-Priced	Project Manager	Possible	Moderate	3	

7.2	Specialized/Monopolized equipment	**Cause:** Sophisticated equipments & technology required. **Risk:** Work delay. **Effect:** Project delay &cost overrun.	CAPEX sholud include specialise machiniers. Not to invest on localised equipments. Development of strong vendor base	Retain-Priced	Project Manager	Likely	High	4	
8	TIME RISK								
8.1	Contract Duration	**Cause:** Contract duration is 63 months. **Risk:** Early Mobilisation is very important for achieving the completion **Effect**: Will have schedule slippage & Cost overrun	We have deployed required equipment & manpower to meet the time line as per clients requirement. As well as development new methodolies.	Retain-Priced	Planning Manager	Possible	Low	2.5	
8.2	Intermediate Milestone	**Cause**: Not Applicable **Risk**: Early Mobilisation is very important **Effect**: Will have schedule slippage & Cost overrun	NA	Retain-Priced	Planning Manager	Unlikely	Low	2	
8.3	Mobilization time	**Cause:** Mobilisation time for cross passage subcontractor & equipments to be speed up. **Risk:** All the required activity needs to be undertaken and finished within the mobilistion period. **Effect**: Will have schedule slippage & Cost overrun	- Based on bore log data, grout pattern to be planned for cross passage. - Excavation work to be started on priority with Hired Equipments.	Retain-Priced	Planning Manager	Possible	Moderate	3	
8.4	Possibility of schedule crashing	**Cause:**No possibility of further crashing of schedule **Risk:** Not Possible **Effect:** N.A	Certain Acitities of the schedule can be crashed, however overall duration cannot be crashed due to interdependancy of civil structures.	Avoidance	Planning Manager	Unlikely	High	3	
C	***OPERATION***								
9	UNKNOWN SITE CONDITION								
9.1	Topographic and geological conditions	**Cause:** Vivid geological strata **Risk:** Delay in tunneling & cross passage excavation **Effect:** Project delay & cost overun	Detailed evaluation of borelogs, wherein required we go for more bore logs.	Retain-Priced	Project Manager	Possible	Moderate	3	
9.2	Floods, Cyclones, Bad Weather and Other Delays	**Cause:** **Risk:** Work stoppage **Effect:** Project delay & cost overun	CAR policy to be taken covering all incidental losses.	Retain-Priced	Contract Manager & Project Manager (Follow-up)	Unlikely	Moderate	2.5	
10	CONSTRUCTION METHOD								

10.1	Grouting	**Cause:** Grout to be desing in accordance with soil condition. **Risk:** Side collapse **Effect:** No effect on cost overrun	Grout sequence to be finalised with proper Mix Desing.	Retain-Unpriced	Quality Manager	Possible	Low	2.5	
10.2	Cross Passage excavation	**Cause:** Innovation to be anticipated. **Risk:** Cross passage works **Effect:** Cost overrun and project delay	New methodology to be planned to construct the cross passages alongwith the live tunneling.	Reduction	Construction Manager	Likely	High	4	
11	DESIGN RISK								
11.1	Client Design	**Cause:** We have undertaken **Risk:** Delay in approval **Effect:** No effect on cost overrun	Proper drawings to be submitted to the cclient in accordance to the contractural requirment and IS codes.	Transfer	Design Team	Possible	Moderate	3	Hire a 3rd party desig ner.
11.2	Our Design	**Cause:** Design responsibility of both Permanent and Temporary structures. **Risk:** No Risk Forseen **Effect:** No effect on cost overrun	Both Permanent and Temporary Designs has been finalised during bid stage and at construction stage design and drawings will be evaluated	Transfer	Design Team	Unlikely	Low	2	
						Average Project Risk		**2.758**	

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