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Probabilistic Approach in Determining Near-Realistic Time Cycle of Critical Activity.

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Abstract—most construction projects uses Critical Path Method extensively for activity planning. Information on past data of similar activities, previous time cycle analyses and availability of fit for construction drawing ensures proper calculation and estimation of time duration for each activity. However, in recent past due to encounter extraordinary geological conditions aka Seri Nallah Zone (SNZ) at Rohtang Tunnel Project has made the conventional methods of estimating time for activities inaccurate and unreliable for further detailed planning. Thus a probabilistic approach was necessary to evaluate and estimate time.

Index Terms: Probabilistic Approach, PERT, Time Cycle Analysis, Triangular Distribution, Pipe Roofing, Beta Distribution, Rohtang Tunnel Project.

1. INTRODUCTION

Rohtang Tunnel Project has encountered extraordinary geological conditions since 2012. This has been characterized by high ingress of water 105-150mm/sec at tunnel face and near about 200-250mm/sec at rear zone. This particular zone was neither foreseen by the Employer during tender stage nor did the designer provide proper FFC drawings for excavation in SNZ.

The excavation works which included extensive ground stabilization works, were carried out mostly as per site instructions by the Engineer on a daily basis. This practice made pre-planning of excavation works very difficult as the quantities and location of tunnel support system was not entirely known to the contractor due to the non-availability of approved FFC drawing in SNZ. The quantities of tunnel support system differed at every chainage from the available FFC drawings of the most relatable Rock Class.

Thus due to high variation and deviation of quantities for rock support from tender rock class resulted in huge slippages of time as compared previous estimations. Standardization of time cycle in SNZ became near impossible by conventional time analysis methods as the previous estimations.

As PERT employs a probabilistic approach to time estimation, where uncertainty is high. Thus, with the nature of uncertainty faced at site, probabilistic approach in Determining near-realistic time cycle of critical activities was chosen for further time estimates.

2. CHOOSING OF CRITICAL ACTIVITY FOR PROBABILISTIC TIME ESTIMATE.

The most critical activity in the project that is affecting project completion and progress is 'Heading Excavation'. As mentioned earlier, the non-availability of approved FFC drawings and construction as per site instructions resulted in high delays in Heading Progress. Moreover, activity planning by CPM in MSP software shows Heading Excavation progress as most critical, while all other preceding activities are all dependent of heading progress.

Thus, heading progress has been chosen where probabilistic approach shall be applied to ensure near realistic time estimate.

3. HEADING ACTIVITY IN SERRI NALLAH ZONE.

The Heading activity in SNZ can broadly be divided in two parts. The quantities of tunnel support is varies according to Site instructions by Engineer. (The methodology of these works will not be discussed. Only

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Time and sequencing of these works shall be enumerated.).

- Pipe Roofing Works
- Excavation under Pipe Roofs.

Pipe Proofing Works:

- Step 1: Drilling and insertion of first layer of 114mm pipes at tunnel face. Number and spacing of pipes is as per site instruction by Engineer.
- Step 2: Insertion of 40mm dia Reinforcement bars and grouting of 1st layer of pipe roof.
- Step 3: Drilling and insertion of second layer of 114mm or 76mm diameter pipes at tunnel face.
- Step 4: Insertion of 40mm dia Reinforcement bars and grouting of 2nd layer of pipe roof.

Excavation Works

- Step 1: Excavation and mucking works.
- Step 2: Installation of Rockbolts.
- Step 3: Installation of 1st layer of Wiremesh and subsequent shotcreting.
- Step 4: Installation of Lattice Girders.
- Step 5: Installation of 2nd layer of Wiremesh and subsequent shotcreting.

The pipe roofing works and subsequent activities in excavation reduced the progress as compared to the distantly relatable rock class.

4. NEED FOR NEW TIME ESTIMATES

The time estimate for the distantly relatable tender rock class is 2.1m per day or 52.5m per month.

However, due to increase rock support a highly reduced progress rate per month was envisaged in FY 2015-16. However, this time estimate did not considered the risks of delays due to increased and varying quantities of rock support and especially the indecisive behaviour of the Engineer and designer. Thus, ultimately the actual progress lagged the planned progress by a huge magnitude.

Thus previous estimates seemed non-applicable due to the trial and error approach of delivering instructions by the Engineer and Designer.

This necessitated the development new time estimates to ensure proper progress planning and further project planning.

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5. METHODOLOGY

Estimating is an inexact art, so we expect that our initial duration estimates have some error in them. What we would really like to know is how much this error is going to affect our estimate of the total project duration. We started with the three-estimate approach to estimating the activity durations.

Next we make the following assumptions:

- The activity durations fit a Beta distribution.
- The range from a to b in the three-estimate approach covers 6 standard deviations.
- The activity durations are statistically independent.
- The critical path now means the path that has the longest expected value of total project time.
- The overall project duration has a normal distribution.

Given these assumptions, the expected value of each activity duration is given in exactly the same way as for the three-estimate approach: (a+4m+b)/6. The variance of each activity duration in this model is [(b−a)/6]2.

Now the expected value of the total project duration is the sum of the expected activity durations along the critical path, which is found in the usual way. Finally the payoff: the variance of the total project duration is the sum of the variances of the activity durations for the activities in the critical path.

6. APPLICATION OF PROBABILISTIC PERT FOR TIME ESTIMATE

Step 1: Consideration of an Ongoing Pipe Proof as control.

Since there was a considerable time gap between the ongoing pipe proof and its preceding pipe roof works, the actual time of the proceeding pipe roofing works did not corresponded to the ongoing pipe roof. The site instructions were considerably different. A double layer pipe roof has been instructed in the present ongoing pipe roof whereas a single layer pipe has been executed in the last pipe roof. Thus Pipe roof No: 35 was chosen as base.

Step 2: Monitoring & Calculation of Actual Activity Time

Actual time of Pipe Roofing Works and Excavation works and other ancillary works is closely monitored and noted down as Shown in Table 1

Table 1: Actual Time of Activities

Activity	Start Date	End Date	Duration
Pipe Roof: Round 35			
Pipe Roofing Works @2417	26 June 15	07 July 15	12
Extension of LG @CH:2411-2413 & Ch:2415-2416+ Extension Drainage Holes	08 July 15	09 July 15	2
Excavation Works (Including Wiremesh, Shotcrete and Temporary Invert) till Ch:2424	10 July 15	09 August 15	31
Total Time for Pipe Roof: Round 35	**20 June 2015**	**02 August 2015**	***45***

Step 3: Monitoring and Calculation of Non-Working Time

In the next step, the total non-working time is monitored and calculated. It is to be noted that only effective equipment breakdown time shall be considered which has affected the main works only. Any disruption due to equipment breakdown in other tunnel works shall not be considered. The table below shows the calculation of non working time.

Table 2: Non Working Time

Non-Working Time	Date	Shift	Days
Shift Change	28 June 15	Night	0.5
Shift Change	12 July 15	Night	0.5
Shift Change	22 July 15	Day +Night	1
Shift Change	26 July 15	Night	0.5
Shift Change	09 July 15	Day +Night	1
Effective Breakdown & Miscellaneous Time Loss	-	-	1.5
Total Time Lost			**5**

Step 4: Probabilistic Time Calculation

The following Time estimate and calculations are done.

1. Actual Time (Ta) : 43 days. (Actual Time spent beyond Chainage 2+417m; 45-2=43 days)

2. Optimistic Time (To): 35.75 days.
   This time is devoid of all non-working time. Additional 5% of Actual Time has been deducted to include better work performance in future.

3. Pessimistic Time (Tp): 47.25days
   This time include all delays. Additional 5% of Actual time has been considered to accommodate other unaccountable delay that has not been encountered in the present Pipe Roof.

4. Likely Time Estimate (Te): 42.5 days.
   This calculated by applying PERT 6 point Estimate. This is also known as Triangular distribution.

$$Te = \frac{To + 4Ta + Tp}{6}$$

$$Thus, \quad Te = \frac{35.75 + 4 * 43 + 47.25}{6}$$

$$= 42.5\ Days$$

5. Calculation of Activity Variance and Activity Standard Deviation:
   Activity Variance:

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$$\sigma^2 = \frac{Tp - To}{6}$$

$$Thus, \quad \sigma^2 = \frac{47.25 - 35.75}{6} = 3.67\ Days$$

Activity Standard Deviation:

$$\sigma = \sqrt{Activity\ Varance}$$

$$Thus, Standard\ Deviation\ \sigma = \sqrt{3.67} = 1.92$$

6. Now, assuming a probability of 80% of all iteration where work shall be completed in the time being calculated.
   Z-value corresponding to 80% probability from Standard Normal Distribution is 0.85.

   Most Likely Estimate = Z value*Standard Deviation + Likely Time Estimate (Te)

   Thus, Most likely time required 7m Progress in heading (Ch 2+417-Ch: 2+424)

$$Time = 0.85\ X\ 1.92 + 42.5 = \mathbf{44.13\ \ Days}$$

$$Therefore, Progress\ Rate = \frac{7}{44.3}\ X\ 30.416\ d$$

$$= \mathbf{4.82\ Meters\ per\ Month}$$

7. RESULT AND FUTURE APPLICATION

Thus, we achieve an progress rate ***4.82 meters per month*** by probabilistic approach.

This progress rate has been taken as basis for further planning and implemented in site plan. Further, equipment and material planning in based on this progress rate.

Effectiveness of Probabilistic Approach.

Proper monitoring was carried out during the following months of tunnel excavation.

To check the effectiveness of this approach the actual progress and actual time has been calculated and the actual monthly progress has been carried out.

Total Progress after 3 pipe Roofs: Ch: 2+417m to Ch: 2+439 is 22 m.

Total Time required for 3 pipe roofs including all delays: (26th June, 2015 to 11 November, 2015) is 138 days.

Therefore, Progress rate per month $= \frac{22}{138}\ X\ 30.416$

= 4.84 Meters per month.

Thus, ensuring the effectiveness of Probabilistic approach in forecasting the desired progress rate.

8. CONCLUSION

The necessity of an effective time estimate was very important from site planning point of view. Detailed monthly resource requirement can be efficiently calculated only when the monthly physical progress is known or forecasted taking all risks and uncertainties into consideration. Probabilistic Approach to estimate near realistic progress has proved to be an effective progress forecasting tool.

Disclaimer: *Some data has been altered to maintain confidentiality regarding actual start and end dates. Duration of activities is un-altered to maintain authenticity of actual calculations.*

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TABLE: STANDARD NORMAL PROBABILITIES

Standard Normal Probabilities

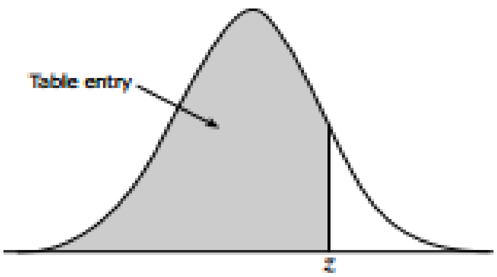

Table entry for z is the area under the standard normal curve to the left of z.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998