RESEARCHERID
THOMSON REUTERS

[Singh* *et al.*, 7(2): February, 2018]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

PROJECT RISK ANALYSIS FOR INFRASTRUCTURE PROJECT USING SIMULATION TECHNIQUE

Manvinder Singh[*1], Debasis Sarkar[2], Divyarajsinh Vara[3]

[*1] Ph.D Scholar, Dept. of Civil Engineering, School of Technology, Pandit Deendayal Petroleum University, Gandhinagar, India

[*2] Associate Professor & Head, Dept. of Civil Engineering, School of Technology, Pandit Deendayal Petroleum University, Gandhinagar, India

[*3] M.Tech student, Infrastructure Engineering & Management Dept. of Civil Engineering, Pandit Deendayal Petroleum University, Gandhinagar, India

DOI: 10.5281/zenodo.1165750

ABSTRACT

Complex mega infrastructure projects are exposed to countless risks due to its complications in different phases of life cycle. Project risk management primarily encompasses of budget and time risks and foreseen and unforeseen uncertainties. For all infrastructure projects, Monte Carlo simulation has extensive applications for risk analysis and application of the simulation technique would make the risk management tools more effective and reliable. This paper is an attempt to compute time overrun and cost overrun of the metro rail project using Expected Value Method and validated by simulation technique to formulate more realistic model. Case study of Ahmedabad elevated metro rail project construction is undertaken for the validation of the simulation method.

KEYWORDS: Project risk; Monte Carlo simulation; metro project; likelihood; impact; time over run; Expected Value Method (EVM); critical path

I. INTRODUCTION

Worldwide over the last 60 years, maximum number of infrastructure projects have experienced huge huge amount of delays and tremendous cost overrun which reduces the likelihood of fruitful completion of the project within approved budget and time. Mass Rapid Transit System (MRTS) projects comprises high degree of risks during the process of piling, pier, segment casting, segment transportation, launching girder, segment erection, jointing and pre-stressing operations. The risks involved and associated during the feasibility phase, land acquisition, tendering design and development phase are also of high severity. This paper aims at computing time and cost overrun by using EVM and validation of the same was carried out by Monte Carlo simulation (MCS) technique. In MCS, random number blocks are selected based on the cumulative weightage range for each major risk category. The calculations for the model are based frequency of values fall under particular selected random block for each major risk category. The results of the model are documented and reiteration is done. When the simulations are accomplished, we got mean simulated weightages for each major risk category. Based upon mean simulated weightage for all major risk categories, simulated cost and time over run is computed and compared with estimated values from EVM .Hence validated by MCS technique.

II. LITERATURE REVIEW

Sarkar and Dutta (2011) had developed a comprehensive RM framework for entire phases of the infrastructure project. Jannadi and Almishari (2003) had established model of risk by probability and severity of impact. However, they have not provided methodology for simulation. Nicholas (2007) stated that, simulation techniques are very essential tool. Sarkar (2011) stated that, the simulation technique is used to validate estimated project cost and time. Kuo and Lu (2013), have expressed their views about construction projects in metropolitan areas and requirement for a trustworthy risk management model for projects. Subramanyam et al. (2012) took the quantitative model based upon AHP. Fuzzy logic integration for daily site reporting and delays was carried out and proved to be fruitful (Oliveros and Fayek), 2005. Peterson et al. (2005) stated that, MCS is very useful for the accurate prediction of completion time and cost of the projects using likelihood concepts.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

III. METHODOLOGY

Sarkar and Dutta (2011) had used EVM. The various nomenclatures are defined below;

Pxy : Probability of x th risk source for y th activity
Wxy : Weightage of x th risk source for y th activity
Ixy : Impact of xth risk source for y th activity
CPF : Composite Probability Factor

Original time estimate (OTE) of the project is computed by CPM network. Similarly, the estimated original cost of project is computed by the cost for each activity is known as the original cost estimate (OCE). The analogous rectified time (rt) or the time required to rectify an activity. The analogous rectified cost (rc) is computed. The summation of the weightages should be equal to 1.

$$\sum_{x=1}^{m} W_{xy} = 1\ for\ all\ \text{y}\ (\text{y} = 1 \ldots \ldots n) \qquad (1)$$

$$Risk\ Cost\ (RC)\ for\ an\ activity\ = \text{Rectified cost}\ x\ Probability \qquad (2)$$

$$Risk\ Time\ (RT)\ for\ an\ activity\ = \text{Rectified time}\ x\ Probability \qquad (3)$$

$$Composite\ Probability\ Factor\ CPF_y = \sum_{x=1}^{m} P_{xy}W_{xy}\ for\ all\ y \qquad (4)$$

$$Composite\ Impact\ Factor\ CIF_i = \sum_{x=1}^{m} I_{xy}W_{xy} \qquad (5)$$

$$0 \le I_{xy} \le 1\ and\ \sum_{x=1}^{m} W_{xy} = 1\ for\ all\ y$$

$$Final\ Expected\ Cost\ (FEC) = OCE + RC \qquad (6)$$

$$Final\ Expected\ Time\ (FET) = OTE + RT \qquad (7)$$

IV. CASE STUDY AND RISK ASSESSMENT

The case study undertaken is Ahmedabad elevated metro rail project starting from Gyaspur depot to Shreyas station. The length of the corridor is 4.6 kms of the Metro's 13.8 km North-South line and the numbers of elevated stations are four (APMC, Jivraj, Rajiv Nagar and Shreyas). The construction is being executed by IL & FS Company Limited. Total 550 piles and 136 piers would be constructed. Total segments to be produced, erected and launched for the viaduct from Gyaspur depot to Shreyas station are 1320 numbers and weight of each segment is 15 tons. IL & FS Company Limited had started piling and pier construction on APMC and Jivraj road. The methodology as discussed was to compute time and cost overrun were used as inputs for formulating further planning steps.

Risk Assessment

The CPM network diagram for the 24 major identified activities of an elevated metro rail project construction is drawn and shown in Fig. 1.The activity description and their nomenclature is tabulated in table 1.The calculations for the various time estimates are tabulated in Table 2.

Table 1. Activity description

Activity	Description
A	Feasibility and DPR risks
B	Risks in tender and award of contract
C	Land Hand Over
D	Drawings receipt
E	Preconstruction Activities - Topographical Survey
F	Preconstruction Activities - Traffic Diversion Plan Preparation, Submission & approval (initial)
G	Preconstruction Activities - Construction Programme

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

H	Preconstruction Activities - Project office
I	Casting Yard Setup
J	Shutter design submission, approval & mobilization
K	Pile Test Road widening & Barricading works at test pile locations
L	Pile Test -Test Pile Casting
M	Pile Test
N	Construction Activities- Road widening & Barricading
O1	Sub-Structure to Pier cap – section 1
O2	Sub-Structure to Pier cap – section 2
P1	Super Structure - Segment Casting- section 1
P2	Super Structure - Segment Casting- section 2
Q	Erection of Launching girder
R1	Segment Erection – section 1
R2	Segment Erection – section 2
S	Obligatory span
T1	Span Alignment & Bearing Fixing – section 1
T2	Span Alignment & Bearing Fixing–– section 2
U	Parapet Casting
V1	Parapet Erection – section 1
V2	Parapet Erection – section 2
W1	Hand Rail Fixing/Cable Tray – section 1
W2	Hand Rail Fixing/Cable Tray – section 2
X1	Expansion Joint Fixing – section 1
X2	Expansion Joint Fixing – section 2

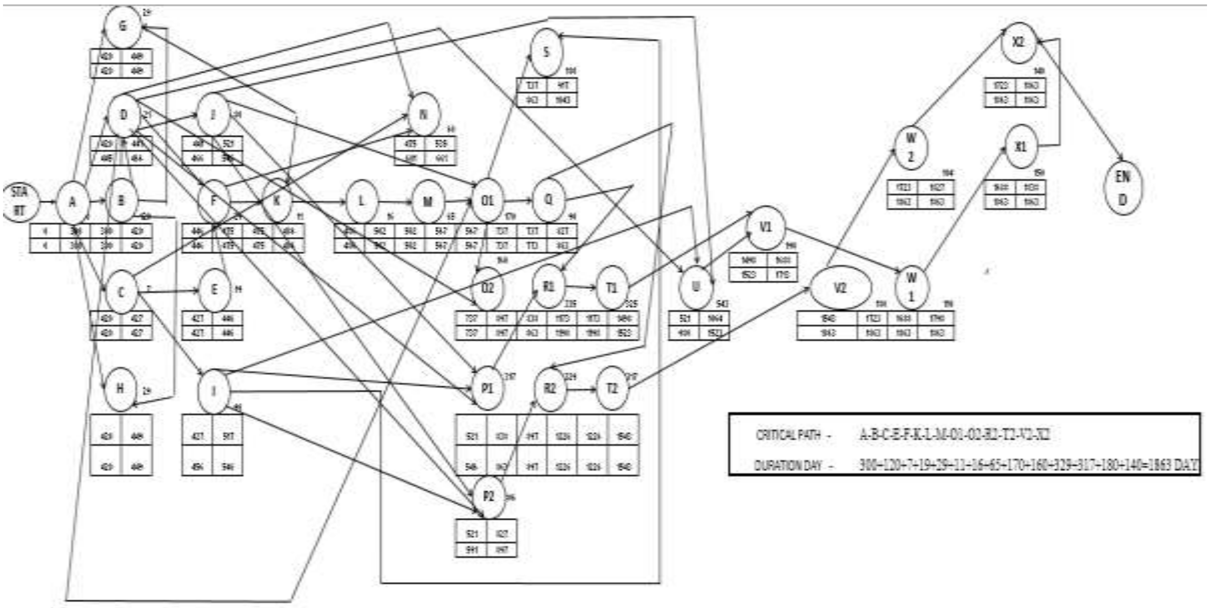

Fig. 1 Network diagram for an elevated corridor metro rail project

Table 2. Relationship of 31 major activities and their time estimates

Activity	Immediate Predecessors	Duration (Days)	ES	EF	LS	LF
A	-	300	0	300	0	300
B	A	120	300	420	300	420
C	A,B	7	420	427	420	427

D	A,B	21	420	441	445	466
E	C	19	427	446	427	446
F	D,E	29	446	475	446	475
G	A,B	29	420	449	420	449
H	A,B	29	420	449	420	449
I	C	90	427	517	456	546
J	D	80	441	521	466	546
K	F	11	475	486	475	486
L	K	16	486	502	486	502
M	L	65	502	567	502	567
N	C,D,F	60	475	535	601	661
O1	D,M	170	567	737	567	737
O2	D,M,O1	160	737	897	737	897
P1	D,I,J	317	521	838	546	863
P2	D,I,J	306	521	827	591	897
Q	O1	90	737	827	773	863
R1	O1,P1,Q	335	838	1173	863	1198
R2	O2,P2,Q	329	897	1226	897	1226
S	O1,I	180	737	917	513	693
T1	R1	325	1173	1498	1198	1523
T2	R2	317	1226	1543	1226	1543
U	D,I,J	543	521	1064	980	1523
V1	U,T1	190	1498	1688	1523	1713
V2	U,T2	180	1543	1723	1543	1723
W1	V1	110	1688	1798	1713	1863
W2	V2	104	1723	1827	1723	1863
X1	V1	150	1688	1838	1713	1863
X2	V2	140	1723	1863	1723	1863

The elevated metro rail corridor project is analyzed by using EVM. For DPR activity (A), the CPF computed by EVM is 0.418 and the related weightage is 0.075 (from questionnaire survey feedback given by 55 experts and brain storming sessions). The OCE is INR 500, 000000; Rectified Cost is INR 260, 000000. OTE is 300 days. Rectified time is 160 days.

Risk Cost = 0.418 x 260 million = INR 108.68 million;
Risk Time (RT) = 0.418 x 160 = 66.88 days.
Thus, FEC = OCE + RC = INR 608.68 x 10^6
FET = OTE+RT = 366.88 days.
Hence FEC and FET is calculated for all the 31 major activities. Henceforth, FEC of the entire project is computed:
FEC = FEC (A) + ………+FEC(X1) + FEC(X2)
FEC = INR 2586.334 x 10^6
Original Cost Estimate = INR 2235 x 10^6
FET = OTE + RT = 2110 days

Table 3. Project final expected cost and time analysis of an elevated metro rail project

OCE (INR million)	RC (INR million)	OTE (days)	RT (days)	FEC (INR million)	FET (days)
2235	351	1863	248	2586	2111

From the Table 3 values, analysis is carried out that FEC of the project is 15.70% greater than Original Cost Estimate .FET of project 13.31% higher than OTE. Both values are within normal range of 30 % (as per experts and literature review) for the budget overrun and schedule overrun.

Path analysis through simulation

Total 19 paths are identified from Figure 1 (network diagram) and simulation is carried out for all the activities as well as paths with respect to time and cost. Simulated time and cost of each path is tabulated in Table 4
.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 4. Path analysis through simulation

Path Sr. no	Path	Simulated Time (days)	Simulated Cost (INR Million)
Path 1	A-C-E-F-K-L-M-O1-Q-R1-T1-V1-X1-X2	1847	952
Path 2	A-C-I-P2-R2-T2-V2-W2-X2	1773	964
Path 3	A-B-C-E-F-K-L-M-O1-O2-R2-T2-V2-X2	1863	1314
Path 4	A-D-U-V1-X1-X2	1454	592
Path 5	A-D-J-P2-R2-T2-V2-X2	1673	889
Path 6	A-D-P1-R1-T1-X1-X2	1778	891
Path 7	A-D-J-O1-O2-R2-T2-V2-X2	1801	937
Path 8	A-D-J-O1-O2-R2-T2-V2-X2	1697	1189
Path 9	A-C-I-U-V1-W1-X1-X2	1530	669
Path 10	A-C-I-P1-R1-T1-V1-X1-X2	1854	968
Path 11	A-C-E-F-N-O1-Q-R1-T1-V1-X1-X2	1815	962
Path 12	A-D-N-O1-O2-R2-T2-V2-X2	1677	1201
Path 13	A-D-N-O1-Q-R1-T1-V1-X1-X2	1781	949
Path 14	A-B-G-K-L-M-O1-O2-R2-T2-V2-X2	1837	1289
Path 15	A-B-N-O1-O2-R2-T2-V2-X2	1776	1290
Path 16	A-B-N-O1-Q-R1-T1-V1-X1-X2	1790	1020
Path 17	A-D-P2-R2-T2-V2-X2	1593	881
Path 18	A-B-C-E-F-N-O1-O2-R2-T2-V2-X2	1831	1304
Path 19	A-C-E-F-N-O1-Q-R1-T1-V1-X1-X2	1815	962

From the above values, it has been analyzed that path 3 (critical path) is having highest time i.e 1863 days and cost i.e. INR 1314 million and path 4 is having lowest time i.e 1454 days and cost i.e. INR 592 million. Therefore path 3 (critical path) is 28% higher time and 21% higher cost as compared with path 4.

Monte Carlo Simulation (MCS) for all 31 major activities

By the application of MCS, the weightages collected and computed for all 31 major risks of elevated metro rail corridor projects would be more accurate. In MCS, random number blocks are selected based on the cumulative weightage range for each major risk category. The calculations for the model are based upon frequency of values fall under particular selected random block for each major risk category. The relative frequency is also calculated. The results of the model are documented and reiteration is done. When the simulations are accomplished, we got mean simulated weightages for each major risk category. Based upon mean simulated weightage for all major risk categories, simulated cost and time over run is computed and compared with estimated values from EVM. One sample simulation is shown in Table 5. The five mean simulated weightages computed for all 31 major activities are tabulated in Table 6.

Table 5. Simulated weightage (Simulation 1)

Activity	Weightage	Cumulative weightage	Random number block	Frequency (from random number table)	Relative frequency	Simulated weightage
A	0.070	0.070	0 - 70	10	0.1	0.1
B	0.060	0.130	71 - 130	9	0.09	0.09
C	0.065	0.195	131 - 195	3	0.03	0.03
D	0.033	0.228	196 - 228	4	0.04	0.04
E	0.013	0.241	229 - 241	4	0.04	0.04
F	0.022	0.263	242 - 263	3	0.03	0.03
G	0.012	0.275	264 - 275	2	0.02	0.02
H	0.040	0.315	276 - 315	2	0.02	0.02
I	0.010	0.325	316 - 325	3	0.03	0.03
J	0.015	0.340	326 - 340	3	0.03	0.03
K	0.030	0.370	341 - 370	3	0.03	0.03
L	0.028	0.398	371 - 398	5	0.05	0.05
M	0.020	0.418	399 - 418	3	0.03	0.03

N	0.016	0.434	419 - 434	4	0.04	0.04
O1	0.050	0.484	435 - 484	5	0.05	0.05
O2	0.050	0.534	485 - 534	4	0.04	0.04
P1	0.044	0.578	535 - 578	3	0.03	0.03
P2	0.044	0.622	579 - 622	2	0.02	0.02
Q	0.036	0.658	623 - 658	1	0.01	0.01
R1	0.055	0.713	659 - 713	3	0.03	0.03
R2	0.055	0.768	714 - 768	4	0.04	0.04
S	0.035	0.803	769 - 803	3	0.03	0.03
T1	0.019	0.822	804 - 822	1	0.01	0.01
T2	0.019	0.841	823 -841	1	0.01	0.01
U	0.017	0.858	842 - 858	2	0.02	0.02
V1	0.017	0.875	859 - 875	2	0.02	0.02
V2	0.017	0.892	876 - 892	2	0.02	0.02
W1	0.038	0.930	893 - 930	3	0.03	0.03
W2	0.038	0.968	931 - 968	3	0.03	0.03
X1	0.016	0.984	969 - 984	2	0.02	0.02
X2	0.016	1.000	985 - 1000	1	0.01	0.01
	1			**100**		**1**

Table 6. Mean simulated weightage of 31 major activities

Activity	Weightage (experts)	Simulated weightage (1)	Simulated weightage (2)	Simulated weightage (3)	Simulated weightage (4)	Simulated weightage (5)	Mean Simulated weightage
A	0.070	0.1	0.09	0.11	0.08	0.12	0.095
B	0.060	0.09	0.1	0.08	0.08	0.11	0.087
C	0.065	0.03	0.01	0.02	0.03	0.01	0.028
D	0.033	0.04	0.03	0.03	0.05	0.02	0.034
E	0.013	0.04	0.03	0.04	0.04	0.01	0.029
F	0.022	0.03	0.02	0.01	0.04	0.01	0.022
G	0.012	0.02	0.02	0.01	0.03	0.03	0.020
H	0.040	0.02	0.04	0.03	0.03	0.04	0.033
I	0.010	0.03	0.03	0.05	0.05	0.03	0.033
J	0.015	0.03	0.04	0.02	0.02	0.02	0.024
K	0.030	0.03	0.03	0.03	0.01	0.03	0.027
L	0.028	0.05	0.04	0.03	0.01	0.04	0.033
M	0.020	0.03	0.03	0.02	0.02	0.03	0.025
N	0.016	0.04	0.03	0.03	0.03	0.02	0.028
O1	0.050	0.05	0.02	0.03	0.03	0.02	0.033
O2	0.050	0.04	0.03	0.02	0.03	0.01	0.030
P1	0.044	0.03	0.02	0.03	0.04	0.04	0.034
P2	0.044	0.02	0.03	0.02	0.02	0.02	0.026
Q	0.036	0.01	0.05	0.05	0.02	0.02	0.031
R1	0.055	0.03	0.03	0.04	0.04	0.04	0.039
R2	0.055	0.04	0.03	0.01	0.01	0.05	0.033
S	0.035	0.03	0.01	0.03	0.03	0.03	0.028
T1	0.019	0.01	0.03	0.02	0.02	0.02	0.020
T2	0.019	0.01	0.02	0.03	0.03	0.03	0.023
U	0.017	0.02	0.02	0.02	0.02	0.02	0.020
V1	0.017	0.02	0.01	0.01	0.01	0.01	0.013
V2	0.017	0.02	0.03	0.05	0.05	0.05	0.036
W1	0.038	0.03	0.04	0.04	0.04	0.03	0.036
W2	0.038	0.03	0.04	0.04	0.04	0.04	0.038
X1	0.016	0.02	0.03	0.02	0.02	0.02	0.021

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

X2	0.016	0.01	0.02	0.03	0.03	0.03	0.023
	1	**1**	**1**	**1**	**1**	**1**	**1**

In order to proof the validation and application of MCS technique, final expected cost and time are calculated using mean simulated weightage of each activity and comparison is done with values obtained by EVM and all values are tabulated in Table 7 and 8.

Table 7. Project final expected cost and time analysis based on simulated weightages (MCS)

OCE (INR million)	RC (INR million)	OTE (days)	RT (days)	FEC (INR million)	FET (days)
2235	371	1863	288	2606	2151

Table 8. Comparative analysis of estimated cost and time derived from EVM and MCS

Risk Weightage (expert survey) -EVM		Risk Weightage (simulated) - MCS	
Project Final Estimated Cost (INR million)	Final Estimated Time (days)	Project Final Estimated Cost (INR million)	Estimated Time (days)
2586	2111	2606	2151

Hence as per above values of final expected cost (FEC) and final expected time (FET) computed from EVM and MCS are having comparable outcomes.

V. CONCLUSION

The risk analysis carried out for elevated metro rail corridor projects divulges that final expected cost (FEC) of project is 15.70% greater than original cost estimate (OCE) and final expected time (FET) of the project is 13.31% greater than original time estimate (OTE) as computed by EVM. As per MCS analysis, FEC of project is 16.5% greater than OCE and the FET is 15.4 % higher than OTE. Thus the analysis prior and post simulation are giving comparable results. Path analysis through Monte Carlo Simulation highlights that path 3 is critical having highest simulated time of 1863 days and simulated cost of INR 1314 million. The likelihood of accomplishment of completion of project within estimated time and cost may be computed from MCS. This combination of EVM and simulation would help to the authorities to formulate risk response strategies accordingly.

VI. REFERENCES

[1] A.V.O. Oliveros and A.R. Fayek, "Fuzzy Logic Approach for Activity Delay Analysis and Scheduling Updating." in JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT, VOL. 131(1), PP 42 – 51, 2005

[2] D. Sarkar, "Simulation application in project risk management for infrastructure transportation project" in INTERNATIONAL JOURNAL OF PROJECT ORGANISATION AND MANAGEMENT, VOL. 3, NOS. ¾, PP. 375-392, 2011

[3] D. Sarkar and G. Dutta, "A Framework of Project Risk Management for the Underground Corridor Construction of Metro Rail." in INTERNATIONAL JOURNAL OF CONSTRUCTION PROJECT MANAGEMENT, VOL.4 (1), PP 21– 38, 2011

[4] H. Subramanyam, P.H Sawant and V. Bhatt, "Construction Project Risk Assessment: Development of Model Based on Investigation of opinion of Construction Project Experts from India." in JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT, VOL.138 (3), PP 409 – 421, 2012

[5] J.M. Nicholas, "Project Management for Business and Technology: Principles and Practice", 2nd ed., Pearson Prentice Hall, New Delhi, 2007

[6] O.A. Jannadi and S. Almishari, "Risk assessment in construction" in JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT, VOL. 129, NO. 5, PP. 492-500, 2003

[7] S.K Peterson, J.D Wardt and J.A. Murtha, "Risk and uncertainty management – best practice and misapplications for cost and schedule estimates" in Proceedings of SPE Annual Technical Conference, Texas, pp.9-12, 2005

[8] W. Roetzheim, "Structured Computer Project Management" in Prentice Hall, New Jersey, 1998

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

[9] Y.C. Kuo, and S.T. Lu, "Using fuzzy multiple criteria decision making approach to enhance risk assessment for metropolitan construction projects" in INTERNATIONAL JOURNAL OF PROJECT MANAGEMENT, VOL. 31, PP 602–614, 2013