Monte Carlo Simulation For Project Schedule Probability Analysis Using Excel

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Abstract— **In this competitive world, with limited resources, cost and time in project management is paid increasing attention. For any kind of project, schedule is essential for successful execution of the project, so the management of schedule is very critical. It is observed that important risk about the construction schedule is time duration risk. Duration risk means the possibility and loss of incompletion of project in the stipulated duration limit. So it is necessary to analyze the Duration of project for which we can use Monte Carlo simulation. For entire project the probability of each work is determined using program evaluation and review technique [PERT] and normal distribution (using area under the curve). On the basis of probability obtained from PERT analysis (Normal or Beta distribution) it simulates the project's duration and analyses the probability of construction schedule by Monte Carlo simulation method. Monte Carlo simulation method is used to simulate the duration for each activity and also the overall project to accurately determine the project completion probability under considering of the changeability and randomness of duration for each activity.**

***Index Terms— PERT, Normal or Beta distribution, Monte Carlo Simulation*.**

I. Introduction (Heading 1)

Construction projects are with many unique features such as long duration, complicated processes used for its execution, environment in which project has to be completed, financial intensity of the project and dynamic organization structures and such organizational and technological complexity generate various risks [8]. If it is observed schedules are essential to the successful execution of projects on time. However, schedule often contain significant uncertainty because risk and uncertainty are ingrained in all construction activities. It is widely accepted that construction project schedule plays major role in project management due to its influence on success of project within stipulated duration. The uncertainty and reliability related issues are becoming more critical in engineering design and analysis, proper assessment of the probabilistic behavior of an engineering system is important [16]. The true distribution for the system response is subject to parameter uncertainty that should be derived. However, due to the complexity of physical systems and mathematical functions, derivation of the exact solution for the probabilistic characteristics of the system response is somewhat difficult, but not impossible. In such cases, viable tool to provide numerical estimation of the stochastic features of the system response is Monte Carlo simulation (MCS). Monte Carlo simulation (MCS) is an influential technique [9]. Two important properties of Monte Carlo simulation are Simultaneous consideration of threats and opportunities, and probability of selecting various criteria. Monte Carlo simulation analysis is a statistical technique that could become as a means for risk assessors to evaluate the uncertainty. This availability has coincided with increasing dissatisfaction with the deterministic or point estimate calculations typically used in quantitative risk assessment; as a result, Monte Carlo simulation is rapidly gaining currency as the preferred method of generating probability distributions of risk.

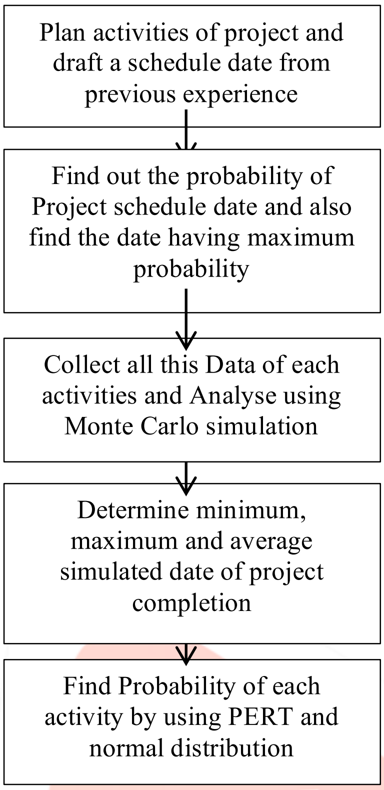
II. Project Schedule Risk Analysis

The purpose of analyzing risk is to help reduce the risk, and also to analyse what would happen in the future such that if any required decision are need be taken [1]. As risk and uncertainty are there in almost every project, therefore, project schedules often contain significant uncertainty in them, which makes scheduling even more difficult [8]. Also, since every project is unique and also conditions for every project are different so it becomes hard to accurately estimate the schedule at an early age. In such case, risk analysis and estimation of schedule are needed to be done efficiently and for this various techniques can be used [9]. To complete a project within a predefined schedule, it is essential to use proper planning tools and techniques. The two most widely used project planning & scheduling techniques PERT (Program Evaluation and Review Technique) & Monte Carlo simulation. [14].

Schedule risk analysis can help project managers identify and mitigate risks and achieve a better project outcomes. Ever since PERT was first put forward by Malcolm and successfully applied in Missile plan, PERT network is extensively used in the estimation of project duration and schedule uncertainty analysis for its simplicity [4]. However, PERT provide good approximation of risk when a project has only one path, it should not be used to analyze risk in schedules that have more than one parallel path because it underestimates the extra risk that occurs. Since almost all real projects have multiple paths, Monte Carlo simulation should be preferred analysis method. Also Monte Carlo simulation results is analyzed by thousands of simulated values.

III. Project Schedule Risk Analysis in Excel Using Monte Carlo Simulation

There are various software used for Project schedule risk analysis with Monte Carlo simulation are Microsoft Project or Primavera, along with Monte Carlo simulation add-ins, such as @Risk or Risk+, also can be done in excel. As Excel is used to with everyone and also easy to use and understand so it would feasible to use excel in it. Entire project can be divided into activities. Here activities probabilities for various conditions are analysed using PERT and normal distribution. Further this data is collected together and used for analysing the project completion probabilities by using Monte Carlo simulation in Ms Excel.



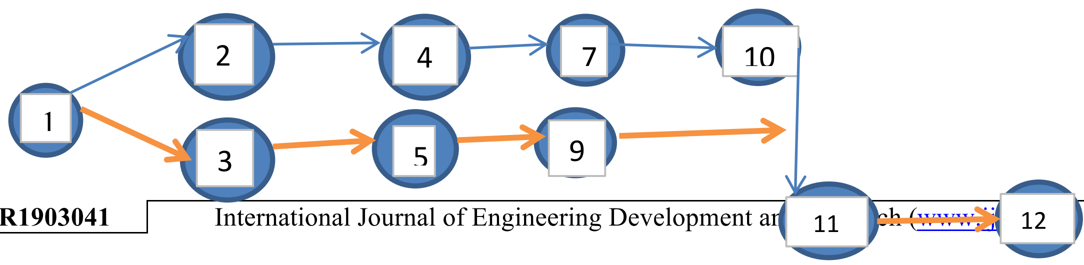
IV. Case Study

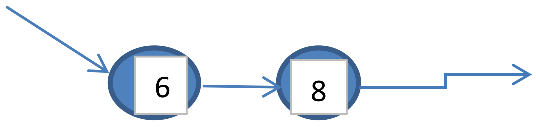
Consider P+2 building (from Ground work to second floor finishing)

4.1.1 Ground work consider following activities –

Table 4.1.1.1 Ground work PERT analysis

Substructure activities	Events	Time (Days)			Expected time (Te)	Variance
		To	Tm	Tp	Te= (To+(4*Tm)+Tp)/6	Variance=((Tp-To)/6)^2
Excavation	1 - 2	8	10	12	10.00	0.4
Excavation with compaction	1 - 3	9	12	15	12.00	1.0
Compaction after excavation	2 - 4	2	4	6	4.00	0.4
PCC after Excavation with compaction	3 - 5	8	10	12	10.00	0.4
PCC with excavation and compaction	3 - 6	3	4	8	4.50	0.7
PCC after excavation with compaction and cutting & binding of footing steel	4 - 7	7	10	13	10.00	1.0
Footing after cutting & binding steel	7 - 10	18	24	30	24.00	4.0
Footing after PCC work	5 - 9	30	38	40	37.00	2.8
Footing with PCC work	6 - 8	26	30	34	30.00	1.8
Concreting for column, plinth beam with steel work	8 - 11	12	15	18	15	1
Concreting for column, plinth beam with steel work	9 - 11	10	12	14	12.0	0.4
Concreting for column, plinth beam without steel work	10 - 11	12	17	18	16.33	1.0
Other work	11 - 12	18	20	22	20.0	0.4





1-3-5-9-11-12 (Critical path) 91.00 days

Table 4.1.1.2 PERT analysis results

Mean= Expected time= Total duration of critical activities=	91
Variance = Sum of variance on critical path	5.1
Standard deviation= Square root of variance	2.26

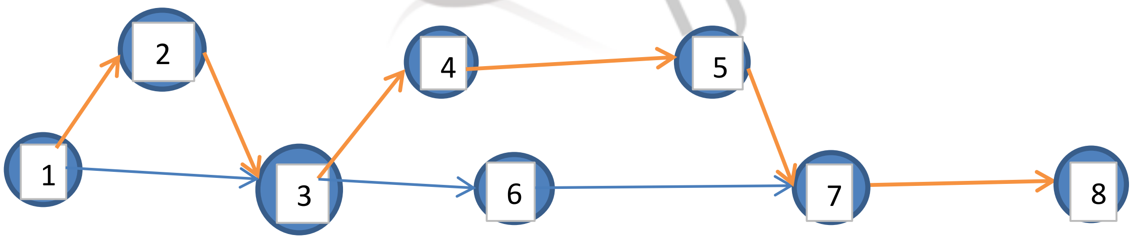
Table 4.1.1.3 Probabilities obtained under the curve assuming normal distribution

Area of curve to left (less than 89)	0.188
Area in between (Between 89 to 93)	0.623
Area of curve to right (Greater than 93)	0.188

4.1.2 Parking floor consider following activities –

Table 4.1.2.1 Parking floor PERT analysis

Substructure activities	**Events**	**Time (Days)**			**Expected time (Te)**	**Variance**
		To	**Tm**	**Tp**	**Te= (To+(4*Tm) +Tp)/6**	**Variance =((Tp-To) /6)^2**
Reinforcement of column and starter casting	1 - 2	3	4	5	4.00	0.1
Reinforcement of column and column casting	1 - 3	4	6	8	6.00	0.4
Column casting after starters	2 - 3	3	4	6	4.17	0.3
Slab casting with councelled electrification	3 - 6	10	13	15	12.83	0.7
Slab casting	3 - 4	7	9	12	9.17	0.7
Electrification	4 - 5	3	4	6	4.17	0.3
Parking tile work after coucelled electrification	6 - 7	6	8	11	8.17	0.7
Parking tile work after electrification	5 - 7	8	10	11	9.83	0.3
Development work	7 - 8	15	18	19	17.67	0.4



1-2-3-4-5-7-8 (Critical path) 49.00 Days

Table 4.1.2.2 PERT analysis results

Mean= Expected time= Total duration of critical activities=	49.00 days
Variance = Sum of variance on critical path	2.0
Standard deviation= Square root of variance	1.414214

Table 4.1.2.3 Probabilities obtained under the curve assuming normal distribution

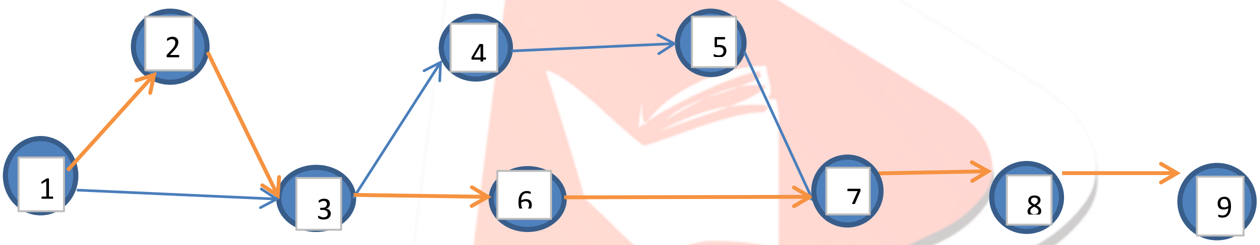
Area of curve to left (before 90)	0.07865
Area of curve to right (between 90 to 98)	0.904403

Area in between	0.016947

4.1.3 First floor consider following activities –

Table 4.1.3.1 First floor PERT analysis

Substructure activities	Events	Time (Days)			Expected time (Te)	Activity variance
		To	Tm	Tp	Te= (To+(4*Tm) +Tp)/6	Variance= ((Tp-To)/6)^2
Reinforcement of column and starter casting	1 - 2	3	4	5	4.00	0.1
Reinforcement of column and column casting	1 - 3	4	6	8	6.00	0.4
Column casting after starters	2 - 3	3	4	6	4.17	0.3
Slab casting with councelled electrification	3 - 6	10	13	15	12.83	0.7
Slab casting	3 - 4	7	9	12	9.17	0.7
Brickwork and plaster	4 - 5	3	4	6	4.17	0.3
Brickwork and plaster with councelled plumbing after coucelled electrification	6 - 7	20	24	26	23.67	1.0
Plumbing and electrification	5 - 7	18	20	23	20.17	0.7
Tiling and door and window fixing	7 - 8	10	11	14	11.33	0.4
Painting	8 – 9	7	9	11	9	0.444



1-2-3-6-7-8-9 (Critical path) 65.00 days

Table 4.1.2.2 PERT analysis results

Mean= Expected time= Total duration of critical activities=	65.00
Variance = Sum of variance on critical path	2.9
Standard deviation= Square root of variance	1.715938

Table 4.1.3.3 Probabilities obtained under the curve assuming normal distribution

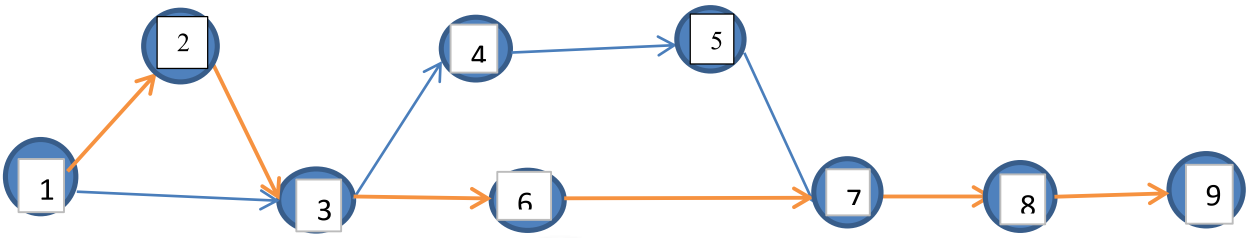
Area of curve to left (before 90)	0.1219
Area of curve to right (between 90 to 98)	0.837896
Area in between	0.040205

4.1.4 Second floor consider following activities –

Table 4.1.4.1 Second floor PERT analysis

Substructure activities	Events	Time (Days)			Expected time (Te)	Activity variance
		To	Tm	Tp	Te= (To+(4*Tm) +Tp)/6	Variance= ((Tp-To)/6)^2
Reinforcement of column and starter casting	1 - 2	3	4	5	4.00	0.1
Reinforcement of column and column casting	1 - 3	4	6	8	6.00	0.4
Column casting after starters	2 - 3	3	4	6	4.17	0.3

Slab casting with councelled electrification	3 - 6	9	11	14	11.17	0.7
Slab casting	3 - 4	8	10	12	10.00	0.4
Brickwork and plaster	4 - 5	12	14	16	14.00	0.4
Brickwork and plaster with councelled plumbing after coucelled electrification	6 - 7	22	26	27	25.50	0.7
Plumbing and electrification	5 - 7	8	10	13	10.17	0.7
Tiling and door and window fixing	7 - 8	10	11	14	11.33	0.4
Painting	8 – 9	7	9	11	9	0.444



1-2-3-6-7-8-9 (Critical path) 65.17 days

Table 4.1.4.2 PERT analysis results

Mean= Expected time= Total duration of critical activities=	65.17
Variance = Sum of variance on critical path	2.6
Standard deviation= Square root of variance	1.624466

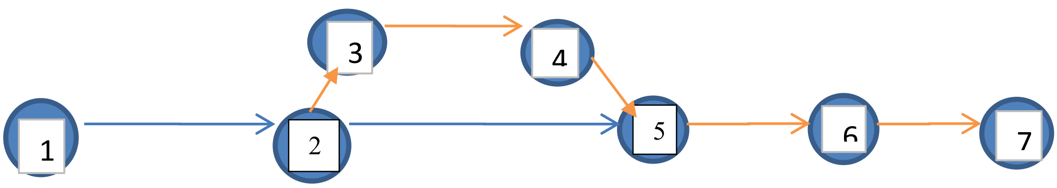
Table 4.1.4.3 Probabilities obtained under the curve assuming normal distribution

Area of curve to left (before 90)	0.109129
Area of curve to right (between 90 to 98)	0.85848
Area in between	0.032391

4.1.5 Third floor consider following activities –

Table 4.1.5.1 Third floor PERT analysis

Third floor						
Substructure activities	**Events**	**Time (Days)**			**Expected time (Te)**	**Activity variance**
		To	**Tm**	**Tp**	**Te= (To+(4*Tm)+Tp)/6**	**Variance=((Tp-To)/6)^2**
Reinforcement of column	1 - 2	1	2	4	2.17	0.2500
Mivan wall and slab deck shuttering simultaneously	2 - 5	2	4	4	3.67	0.1111
Mivan wall shuttering	2 - 3	1	3	4	2.83	0.2500
Slab deck panel laying	3 - 4	1	2	3	2.00	0.1111
Slab reinforcement	5 - 6	1	1	3	1.33	0.1111
Slab casting	6 - 7	1	1	2	1.17	0.0278



Summation of path	**Duration**

1-2-3-4-5-6-7	**9.50**	**Days**
1-2-5-6-7	8.33	Days

Mean= Expected time= Total duration of critical activities=	9.50
Variance = Sum of variance on critical path	0.8
Standard deviation= Square root of variance	0.866025404

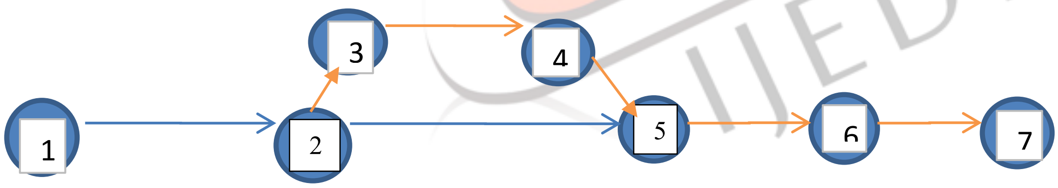
Assuming normal distribution probabilities of work completion

Area of curve to left (before 61)	0.010460668
Area of curve to right (between 90 to 98)	0.9895374
Area in between	0.010460668

4.1.6 Fourth floor consider following activities –

Table 4.1.6.1 Fourth floor PERT analysis

Fourth floor						
Substructure activities	**Events**	**Time (Days)**			**Expected time (Te)**	**Activity variance**
		To	**Tm**	**Tp**	**Te=(To+(4*Tm)+Tp)/6**	**Variance=((Tp-To)/6)^2**
Reinforcement of column	1 - 2	1	1	2	1.17	0.0
Mivan wall and slab deck shuttering simultaneously	2 - 5	2	3	4	3.00	0.1
Mivan wall shuttering	2 - 3	1	2	3	2.00	0.1
Slab deck panel laying	3 - 4	1	1	3	1.33	0.1
Slab reinforcement	5 - 6	1	2	3	2.00	0.1
Slab casting	6 - 7	1	1	1	1.00	0.0



Summation of path	**Duration**	
1-2-3-4-5-6-7	**7.50**	**days**
1-2-5-6-7	7.17	days

Mean= Expected time= Total duration of critical activities=	7.50
Variance = Sum of variance on critical path	0.3
Standard deviation= Square root of variance	0.5

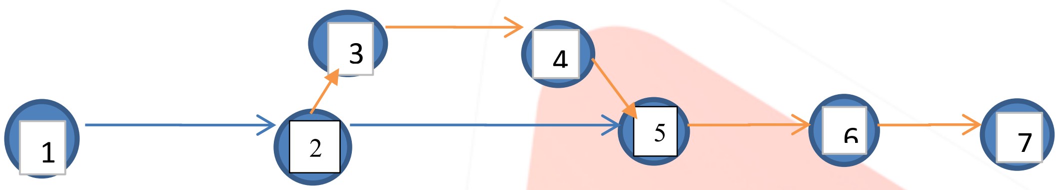
Assuming normal distribution probabilities of work completion

Area of curve to left (before 61)	0.02275
Area of curve to right (between 90 to 98)	0.9544997
Area in between	0.02275

4.1.6 Fifth floor consider following activities –

Table 4.1.6.1 Fifth floor PERT analysis

Fifth floor						
Substructure activities	**Events**	**Time (Days)**			**Expected time (Te)**	**Activity variance**
		To	**Tm**	**Tp**	**Te= (To+(4*Tm)+Tp)/6**	**Variance=((Tp-To)/6)^2**
Reinforcement of column	1 - 2	2	2	3	2.17	0.0
Mivan wall and slab deck shuttering simultaneously	2 - 5	1	3	4	2.83	0.3
Mivan wall shuttering	2 - 3	2	2	3	2.17	0.0
Slab deck panel laying	3 - 4	1	2	2	1.83	0.0
Slab reinforcement	5 - 6	1	2	3	2.00	0.1
Slab casting	6 - 7	1	1	1	1.00	0.0



Summation of path	**Duration**	
1-2-3-4-5-6-7	9.17	days
1-2-5-6-7	8.00	days

Mean= Expected time= Total duration of critical activities=	9.17
Variance = Sum of variance on critical path	0.1
Standard deviation= Square root of variance	0.28867513

Assuming normal distribution probabilities of work completion

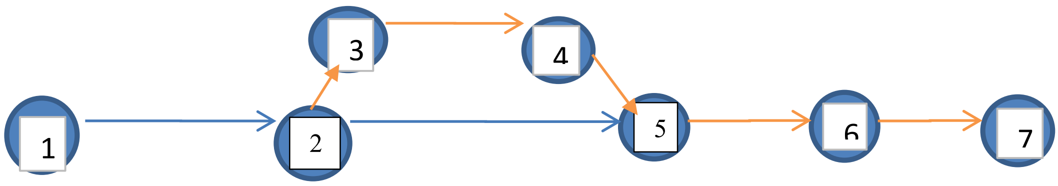
Area of curve to left (before 61)	0.000266
Area of curve to right (between 90 to 98)	1.0000000
Area in between	2.1311E-12

4.1.6 Sixth floor consider following activities –

Table 4.1.6.1 Sixth floor PERT analysis

Sixth floor						
Substructure activities	**Events**	**Time (Days)**			**Expected time (Te)**	**Activity variance**
		To	**Tm**	**Tp**	**Te= (To+(4*Tm)+Tp)/6**	**Variance=((Tp-To)/6)^2**
Reinforcement of column	1 - 2	1	1	2	1.17	0.0
Mivan wall and slab deck shuttering simultaneously	2 – 5	1	2	3	2.00	0.1
Mivan wall shuttering	2 - 3	2	2	3	2.17	0.0
Slab deck panel laying	3 - 4	1	2	3	2.00	0.1

Slab reinforcement	5 – 6	1	2	2	1.83	0.0
Slab casting	6 – 7	1	1	1	1.00	0.0



Summation of path	**Duration**	
1-2-3-4-5-6-7	8.17	days
1-2-5-6-7	6.00	days

Mean= Expected time= Total duration of critical activities=	8.17
Variance = Sum of variance on critical path	0.2
Standard deviation= Square root of variance	0.40824829

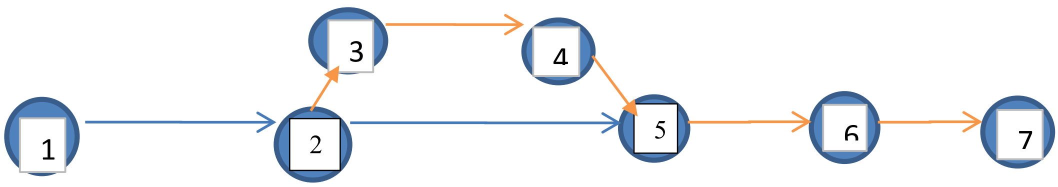
Assuming normal distribution probabilities of work completion

Area of curve to left (before 61)	0.00715294
Area of curve to right (between 90 to 98)	0.9928466
Area in between	4.8168E-07

4.1.7 Seventh floor consider following activities –

Table 4.1.7.1 Seventh floor PERT analysis

Seventh floor						
Substructure activities	**Events**	**Time (Days)**			**Expected time (Te)**	**Activity variance**
		To	**Tm**	**Tp**	**Te= (To+(4*Tm)+Tp)/6**	**Variance=((Tp-To)/6)^2**
Reinforcement of column	1 - 2	2	2	3	2.17	0.02778
Mivan wall and slab deck shuttering simultaneously	2 - 5	1	2	3	2.00	0.11111
Mivan wall shuttering	2 - 3	1	1	2	1.17	0.02778
Slab deck panel laying	3 - 4	1	2	3	2.00	0.11111
Slab reinforcement	5 - 6	2	2	3	2.17	0.02778
Slab casting	6 - 7	1	1	2	1.17	0.02778



Summation of path	**Duration**	
1-2-3-4-5-6-7	8.67	days
1-2-5-6-7	7.50	days

Mean= Expected time= Total duration of critical activities=	8.67
Variance = Sum of variance on critical path	0.22222
Standard deviation= Square root of variance	0.4714045

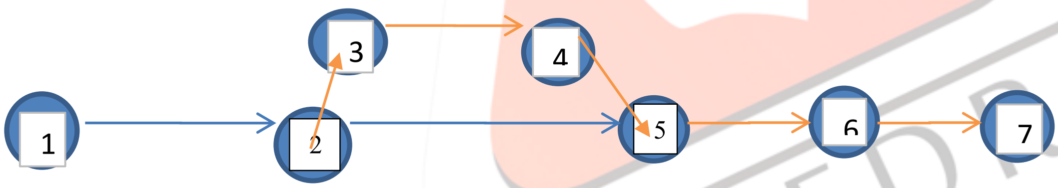
Assuming normal distribution probabilities of work completion

Area of curve to left (before 61)	9.831E-11
Area of curve to right (between 90 to 98)	0.9999890
Area in between	9.831E-11

4.1.8 Eighth floor consider following activities –

Table 4.1.8.1 Eighth floor PERT analysis

Eighth floor						
Substructure activities	**Events**	**Time (Days)**			**Expected time (Te)**	**Activity variance**
		To	**Tm**	**Tp**	**Te= (To+(4*Tm)+Tp)/6**	**Variance=((Tp-To)/6)^2**
Reinforcement of column	1 - 2	2	2	3	2.17	0.0
Mivan wall and slab deck shuttering simultaneously	2 - 5	1	2	3	2.00	0.1
Mivan wall shuttering	2 - 3	2	2	2	2.00	0.0
Slab deck panel laying	3 - 4	2	2	2	2.00	0.0
Slab reinforcement	5 - 6	1	2	2	1.83	0.0
Slab casting	6 - 7	1	1	1	1.00	0.0



Summation of path	**Duration**	
1-2-3-4-5-6-7	9.00	days
1-2-5-6-7	7.00	days

Mean= Expected time= Total duration of critical activities=	9.00
Variance = Sum of variance on critical path	0.1
Standard deviation= Square root of variance	0.23570226

Assuming normal distribution probabilities of work completion

Area of curve to left (before 61)	1.1045E-05
Area of curve to right (between 90 to 98)	1.0000000
Area in between	0

4.2 After feeding following data to excel and simulating it

Table 4.2.1 Data for Monte Carlo simulation

Simulating all the data together obtained from above analysis (PERT and then normal distribution of ground work, parking floor, first floor and second floor)

Activity	**Lookup column**	**Activity time (Days)**	**Probability**	**Check**
Ground work	0	81	0.03842	

	0.038421622	91	0.98253	
	1.02094776	100	0.01350	1.034
Parking floor	0	45	0.08849	
	0.0885	48	0.90440	
	0.9929	52	0.02143	1.014
First floor	0	41	0.12190	
	0.121899626	45	0.83790	
	0.959795213	48	0.04020	1.000
Second floor	0	37	0.10913	
	0.109128893	41	0.85848	
	0.967609109	44	0.03239	1.000
Third floor	0	6	0.01046	
	0.010	10	0.98954	
	1.000	15	0.01046	1.010
Fourth floor	0	6	0.02275	
	0.023	8	0.95450	
	0.977	9	0.02275	1.000
Fifth floor	0	7	0.00027	
	0.000	10	1.00000	
	1.000	12	0.00000	1.000
Sixth floor	0	6	0.00715	
	0.007	8	0.99285	
	1.000	10	0.00000	1.000
Seventh floor	0	5	0.00000	
	0.000	9	0.99999	
	1.000	12	0.00000	1.000
Eighth floor	0	6	0.00001	
	0.000	9	1.00000	
	1.000	13	0.00000	1.000

RESULTS AND ANALYSIS

By using Monte Carlo simulation above data is simulated 10000 times in excel and the following results are obtained

Analysis	
Expected duration	281.7527091
Mean of simulation values	229.895
Standard deviation of simulation values	2.808
Minimum of simulation	211
Maximum of simulation	238
x	232
P(X<=225)	0.938789822

Project Start date	10-08-2018
Estimated project completion Date	18-05-2019
Estimated project completion Date as per Critical path method	28-04-2019
Average simulated date of project completion.	27-03-2019

Minimum simulated date of project completion.	07-03-2019
Maximum simulated date of project completion.	04-04-2019
Most probable project completion date	31-03-2019

CONCLUSION

From the above study it is concluded that there are various techniques for project schedule probability analysis but everyone has its own drawbacks. It is observed that Monte Carlo simulation technique is most feasible technique so its demand for estimating project schedule risk is increasing. It was found that data used for Monte Carlo simulation was taken from previous experience data but also we can estimate the each activities probability from PERT and normal distribution. Monte Carlo simulation can be easily implemented in Ms Excel. It uses 10000 times simulated data for analysis. In above case study we found that Monte Carlo simulation can be used to determine the probability of project completion date which is estimated at site. The expected date of project completion is 282 days but as per simulation results obtained 238 days is maximum simulated date of project completion. So it is found that we can complete project before the expected schedule date.

V. ACKNOWLEDGMENT

I am very thankful to my project guide Dr. S. K Kulkarni for the opportunity given to carry out the project titled "Project Schedule Probability Analysis Using Monte Carlo Simulation in Excel" His guidance throughout year has helped me to progress in the right direction. Also, I would like to express my gratitude to Dr. S K Kulkarni HOD-Civil and Dr. L. V. Kamble Principal, D Y Patil of Institute of engineering and Technology, Ambi & Dr. R. V. Kherde Principal, D Y Patil of school of engineering, Ambi. Also to those who have contributed directly and indirectly for the progress in Project Work. Finally, I would like to thank PG Coordinator (for Civil) – Himanshu Ahire for their guidance and support to complete Project.

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