Project Simulations: Monte Carlo Analysis Made Simple

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Predicting the project completion times has been one of the major challenges of Project Managers. Project Schedule overruns are quite common due to the high uncertainty in estimating activity durations, lack of project completion historical data, organization culture, inadequate skill sets, complex and progressive elaborative nature of projects etc.

PMI's Pulse of the Profession™ research, which is consistent with other studies, shows that fewer than two-thirds of projects meet their goals and business intent (success rates have been falling since 2008), and about 17 percent fail outright.

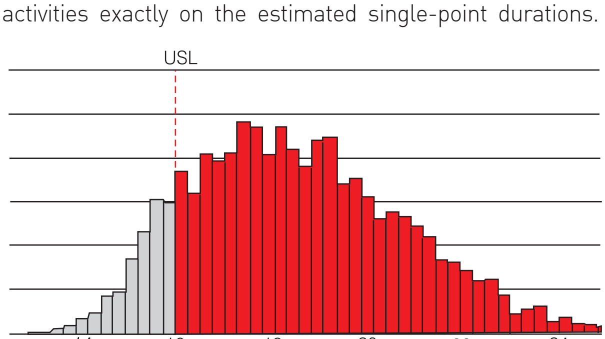
Failed projects waste an organization's money: for every US$1 billion spent on a failed project, US$135 million is lost forever.. unrecoverable.

Another report on Infrastructure Project Schedule and Cost Overruns by PMI-KPMG, released in 2013, says that 79 percent of the survey respondents agree that the infrastructure sector in India faces shortage of skilled project managers with the prerequisite skill set, which results in time/schedule overruns. One of the reasons for inefficient project delivery is the paucity of skilled project managers in the infrastructure sector.

In the aftermath of such shocking survey findings, predicting an achievable project completion time has become more important today than ever before due to the high Liquidated Damages (LD) or Penalty charges for late completion and growing dissatisfaction amongst the Clients and the Public.

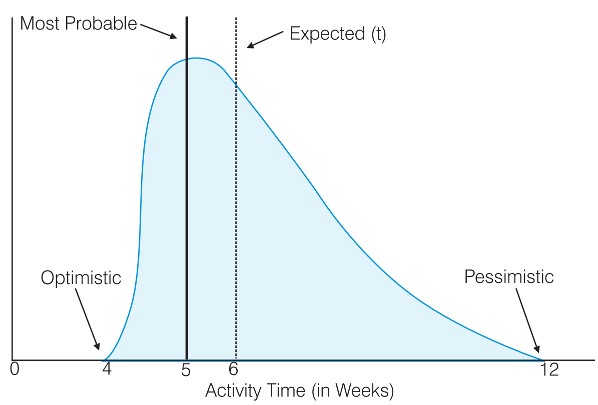
The Drawbacks of Traditional CPM Technique

Deterministic, single point, estimates of project activities are highly risky as it is impossible to complete all the project activities exactly on the estimated single-point durations.



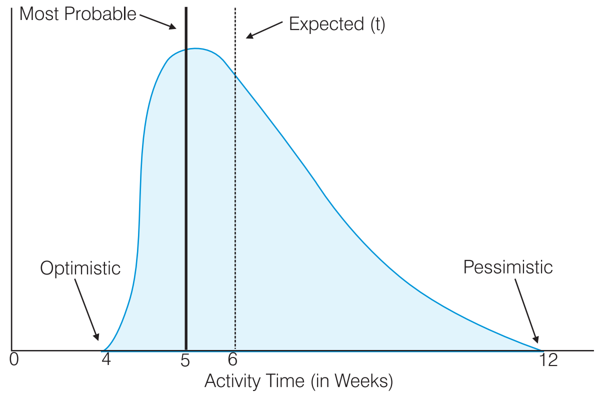
simulation indicates that you can expect 86.86% of the T values to fall outside of the specification

Moreover, most estimators tend to estimate activity durations that is closer to optimistic estimates than to the pessimistic durations. The most-likely estimates are the Modal estimates and the traditional Critical Path Method (CPM), assumes activities are Normally distributed. In a Normal distribution, the modal estimates have only 50% chances of being completed within or less than the estimated duration and hence the critical path duration. This means, we typically start a project with an estimated project completion time found by CPM that has theoretically 50% chances of being EXCEEDED from the Day-1 of kicking-off the project.



Why Probabilistic Method (PERT): Models that use three-point estimates, such as PERT model, reduce uncertainty in the project completion times by taking into account the Optimistic (To), Most-likely (Tml) and Pessimistic (Tp) to some extent. The width of the range (Tp -To) indicates the degree of the risk in each activity duration. While the probabilistic estimates can give us three different project completion times, each based on either the To or Tml or Tp, we generally calculate the project completion time based on an equivalent single-point expected duration by assigning appropriate weights to each of the 3 durations. For example, the PERT model, which assumes Beta distribution, uses the following formula to calculate the expected duration,Te.

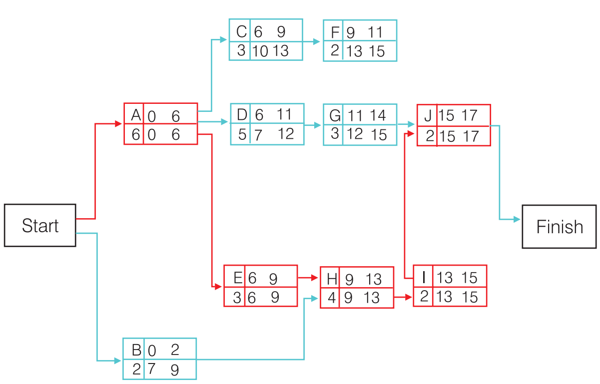
Using the PERT's 3-point estimates of activities whose durations are in weeks, we get the following PERT Network Diagram to calculate the critical path. The expected durations so calculated are then used as single-point durations in the traditional CPM method to arrive at the critical path duration. Please note that the Te values have been used as



Expected duration,Te = (To + 4Tml +Tp) / 6

Activity	Optimistic (To)	Most Likely (Tml)	Pessimistic (Tp)
A	4	5	12
B	1	1.5	5
C	2	3	4
D	3	4	11
E	2	3	4
F	1.5	2	2.5
G	1.5	3	4.5
H	2.5	3.5	7.5
I	1.5	2	2.5
J	1	2	3

the fixed length or known activity durations (similar to the CPM) and the critical path is found by the traditional CPM way using forward and backward passes to calculate the total float of each activity. The critical path is shown below in red color.



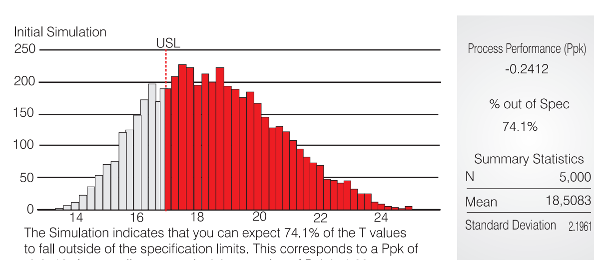
The Critical Path Duration , T = A + E + H + I + J = 6 + 3 + 4 + 2 + 2 = 17 Weeks

Unfortunately this PERT project duration, found by adding the critical activities, also enjoys ONLY a 50% chances of completion. The project completion time, irrespective of the distribution shapes of the critical activities, tends to follow approximately normal distribution if there are sufficiently large number of activities (say, →30) in the critical path, according to the Central Limit Theorem (CLT).

Hence, our problem is still not solved fully as PERT-based project completion time is nothing but a glorified-CPM-based completion time, which, according to the CLT, has only 50% chances of completion. In the above PERT Network diagram we can see the single-point project completion time as 17 weeks. But, it is dangerous to proceed on a single-point completion time that has only 50% chances of completion.This is where simulation techniques, such as Monte Carlo, come handy to arrive at various project completion times along with their probability of completion so that we can plan suitable contingency reserves (CR), in terms of project completion times, needed to ensure at least a 90-95% probability of completion (as against 50% by CPM or PERT methods) during the risk management planning stage itself.

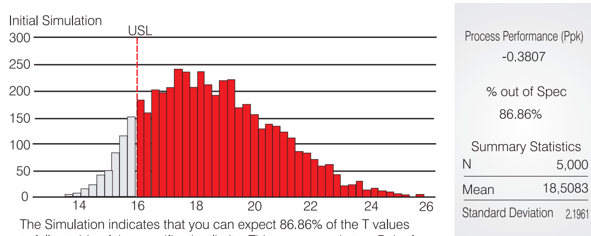
Monte Carlo Simulation

In Monte Carlo simulation, the durations of critical path activities are simulated to take on random values between their Low and High values, depending on the distributions assumed, using a random number generator until all the specified number of simulations, say 5000, are exhausted. For each simulation, a set of project completion time and its probability of completion is calculated and stored. When all the 5000 simulations are done, we get 5000 project completion times and their probability values. These values are then plotted as a Histogram with an S-curve of cumulative probability values superimposed on the Histogram so that we can find the project completion time for any given probability of success wanted by the Client. Monte Carlo Simulation outputs (with 5000 simulations using the software Devize® from Minitab® Inc) for various target project completion times are given below. Such simulated outputs help determine the Contingency Reserves (CR) needed in terms of the project completion time for better planning and completion assurance to the Clients.



The 5000-simulated output above predicts that the single-point Critical Path duration of 17 weeks has only 25.9% chances of completion or 74.1 % chances of failure (being exceeded). The next simulation to find the probability of completing the project ahead of schedule by 1 month possibly by fast-tracking shows that the chances of completing the project in 16 weeks (as against baseline duration of 17 weeks from CPM) are only 13.14%. Such predictions are very helpful to project managers in effective planning and deployment of project resources.

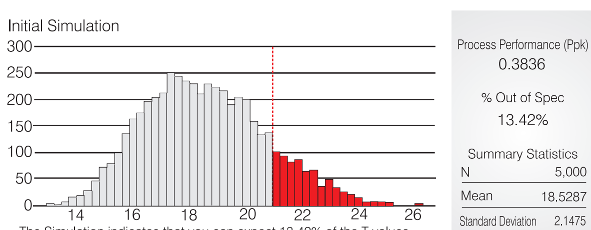
Next, if the Client wants to know or predict the project completion duration that has at least a 85% chances of success, we can easily do that with the Minitab® Inc new simulation software Devize®. From the simulated sketch below, we can see that the target completion time of 21 weeks (



The Simulation indicates that you can expect 86.86% of the T values to fall outside of the specification limits. This corresponds to a Ppk of 0.3807. A generally accepted minimum value of Ppk is 1.33.

USL=21 weeks) has 86.58% chances of project being completed within 21 weeks.

If the Project Manager wants to submit a completion time that has at least 85% chances of completion with all the duration combinations of the critical path activities taken into account, then he or she should commit a completion time of 21 weeks as against the contractual completion time of 16 weeks which, in fact, had only 13.14% of success as seen before.



The Simulation indicates that you can expect 13.42% of the T values to fall outside of the specification limits. This corresponds to a Ppk of 0.3836. A generally accepted minimum value of Ppk is 1.33.

Conclusion

Monte Carlo simulation is a boon to the Project Managers, in general and to the Risk Managers, in particular for simulating various possible combinations of the predictor variables within their range of values. With software such as Devize®, the analysis has been made simpler and intuitive to mitigate the overall project schedule risks to an acceptable threshold. Monte Carlo simulations help the project managers arrive at several possible project completion times along with their associated probabilities of success to take more informed project decisions in today's highly complex project world so as to become a leader in the international and domestic construction industry by completing projects within the agreed time.

References

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The author, Ondiappan Arivazhagan, "Ari", is an Honors graduate in Civil / Structural Engineering from University of Madras. He is a certified PMP, PMI-SP, PMI-RMP from PMI, USA. He is also a Master Black Belt in Lean Six Sigma and has done Business Analytics from IIM, Bangalore. He has 30 years of professional global project management experience in various countries around the World and has almost 14 years of teaching / training experience in Project management, Analytics, Risk Management and Lean Six Sigma .He is the Founder-CEO of International Institute of Project Management (IIPM), Chennai and can be reached at askari@iipmchennai.com

Cellulose Nanocrystals Shown to Strengthen Concrete

Researchers at Purdue University found that the Cellulose Nanocrystals (CNCs), tiny structures derived from renewable sources can increase the tensile strength of concrete by 30 percent. CNC is a rich material that can be obtained from the byproducts of cellulose feed stocks such as paper, bioenergy, agriculture and pulp industries. They are extracted from structures called cellulose micro-fibrils, which help to give plants and trees their high strength, lightweight and resilience. The study shows that the new biomaterial can have potential applications in various fields such as strengthening construction materials and automotive components. Limitation of today's concrete is that not all of the cement particles are hydrated after being mixed, leaving pores and defects that hamper strength and durability. The CNC mixed concrete will increase hydration and subsequently alter the structure of concrete and strengthen it. As a result, less concrete needs to be used.