# Building Predictability in Project Performance using Applied Statistics

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## 1.1 Abstract

Objective: Explore the possibility of using “applied statistics” to improve predictability in project performance.

**Scope**: Usage of statistical techniques within the 9 knowledge areas of PMBOK

Result: Paper would state the specific areas within the PMBOK where statistics can be used to improve predictability of project performance. For example how statistics can be used to improve predictability in

Project Planning (Estimation)

Monitoring & Control (Building an Early Warning System)

Business Value: Projects by definition have an element of uniqueness in the outcome. Project Performance Management is the art & science of increasing the “probability of success (performance)” of achieving the unique outcome within the given constraints (i.e. scope, time, cost, quality, risk & resource).

Usage of statistical techniques in association with PMBOK can facilitate increased project performance & hence business benefits associated with the project.

Key Differentiator: Focused effort on improving predictability in project performance using proven practices in “applied statistics” & project management.

The paper would be focused on “applied project management” with examples & scenarios.

## 1.2 Keywords

Predictability, Performance, Statistics,

## 1.3 Introduction

***Would you go to an orthopaedist who did not use X-rays?***

J.M. Furbringer

A project manager not using proven tools to develop estimates would be at an inherent disadvantage of being inaccurate beyond acceptable limits.

Project management is the art & science of using tools to increase the probability of success for the unique outcomes to be produced by projects. Project manager have to forecast the estimated completion date& cost. In fact the credibility of the project manager is based on the individualsability to forecast the estimates along with the associated accuracy.

Quantitative techniques based on statistics help the project manager to quantify the project performance & hence manage projects with improved predictability.

### What is Statistics?

Statistics is set of tools for collecting, organizing, presenting and analysing numerical facts or observations. Statistics has empirical roots and provides tools for forecasting using data & models.

Progressive elaboration is an essential characteristic of projects and hence estimates have to get refined in accuracy with additional availability of information. This is only possible if the project team uses pre-defined scientific models to develop the estimates.

There are no facts about the future—everything that hasn't happened is only an estimate.

***"If you are going to predict, predict often…"***

Milton Friedman, Nobel laureate

There is a need to explore statistical techniques that can be used to predict project quality, time & cost estimates with acceptable accuracy & confidence levels.

The paper illustrates through selected scenarios the relevance of statistical techniques in project estimation & performance management. The paper is not a primer on statistical techniques or project management. The contents of the paper are neither exhaustive nor definitive.

## 1.4 Scenario-1: Predicting Critical Activities on the schedule using Criticality Index

Lets take a scenario where a project with 5 activities as mentioned in figure:1 have to be completed. The project manager uses 3 point estimation for the duration to arrive at Optimistic (O), Pessimistic (P) & Most Likely (ML) values.

| Duration Estimate | | | |
|---|---|---|---|
| Task | O | ML | P |
| A | 2 | 3 | 6 |
| B | 2 | 4 | 7 |
| C | 2 | 3 | 8 |
| D | 2 | 4 | 9 |
| E | 2 | 3 | 10 |

**Figure:1**

The project manager can prepare a schedule using any popular scheduling tool, which uses the critical path method as the algorithm.The project manager would communicate the scenario 1 of 3 as shown in figure:2.

One of the purposes for communicating the schedule is to know where should the project manager & team focus attention in order to better manage the project critical activities i.e. the critical path.

A static view of the critical path considering the most likely estimate assumes that no activity would start before or latter than estimated.

As seen in the figure:2 scenario 1, 2 & 3, depending on the variation in the duration estimates the list of critical activities identified changes. Most projectsreality is that each activity has a different likelihood with respect to duration. It is the dynamic impact of the individual activity likelihoods that should be factored to be able to predict the critical activities on the schedule.

With the additional information of 3-point estimate for each activity duration the project manager can perform a sensitivity analysis to arrive at the activity criticality index as shown in figure:3

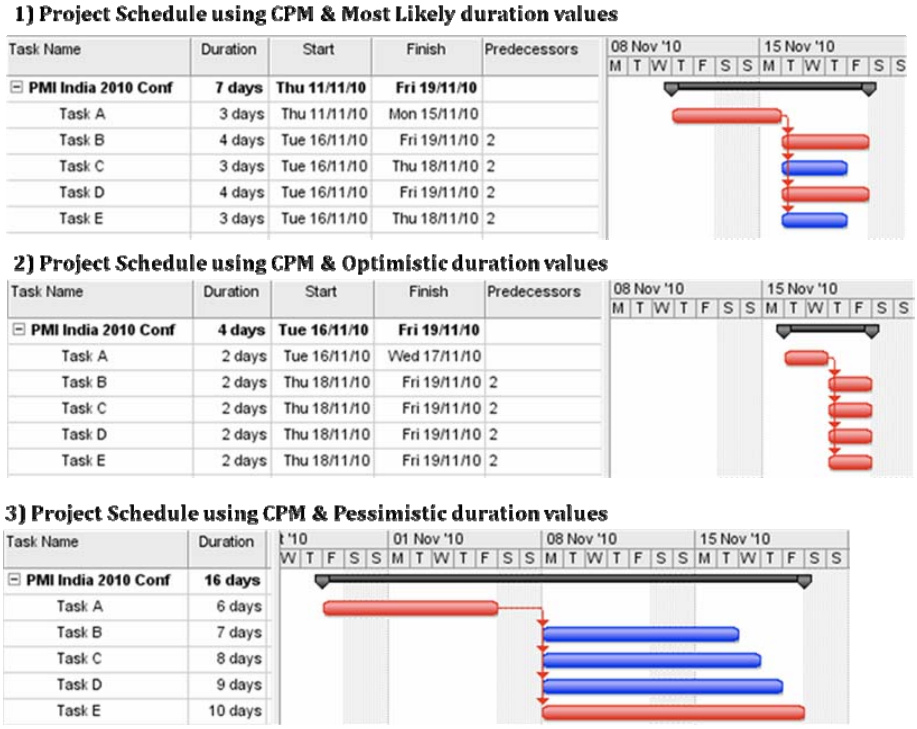


**Figure:2** Project Schedule using CPM

**Sensitivity analysis** is the study of how the variation (uncertainty) in the output of a mathematical model can be apportioned, qualitatively or quantitatively, to different sources of variation in the input of the model.It is a technique for systematically changing parameters in a model to determine the effects of such changes.

Sensitivity analysis can be useful to project manager for a range of purposes, including:

- Support decision making (e.g. testing the robustness of an estimate);
- Enhancing communication from project manager to key stakeholders (e.g. by making recommendations more credible, understandable, compelling or persuasive);
- Increased understanding or quantification of the system (e.g. understanding relationships between project variables)

| Criticality Index | |
|---|---|
| Task A | 100% |
| | |
| Task B | 25% |
| | |
| Task C | 27% |
| | |
| Task D | 40% |
| | |
| Task E | 40% |

**Figure:3** Activity Criticality Index derived after a Sensitivity analysis

## 1.5 Criticality index

Criticality Index is mainly used in risk analysis. The Criticality Index of an activity (task) can be expressed as a ratio (between 0 and 1) but is more often expressed as a percentage. During a ( e.g. Monte Carlo) simulation tasks can join or leave the critical path for any given iteration. The Criticality Index expresses how often a particular task was on the Critical Path during the analysis. Tasks with a high Criticality Index are more likely to cause delay to the project as they are more likely to be on the Critical Path. If a task does not exist for some iterations (e.g. it is probabilistic) then it is marked as not being critical. For example a task that existed for 50% of the iterations and was critical 50% of the time it existed would have a Criticality Index of 25%.

## 1.6 Benefits of calculating activity criticality index

The Criticality Index allows you to identify tasks that are likely to cause delays to the project. By monitoring tasks with a high Criticality Index a project is less likely to be late. If a task has a 100% Criticality Index it means that during the analysis no matter how the task durations varied, the critical path always included the task. The task is therefore likely to be key in completing the project on time. Conversely tasks with a low or zero Criticality Index are much less likely to cause a delay in the project finish date.

## 1.7 Scenario 2: Estimating the Project Schedule & Cost using Monte Carlo

What is the Project Completion date?

What is the BAC / EAC?

All project managers would be expected to respond to the above questions& more often the project manager would respond back based on

- Rolled-up figures from a bottom-up estimation or
- Analogous figures from past experience or
- Combination of 3-point technique & one of the above estimation techniques

The inherent limitation of the above estimation techniques is they do not take into account the statistical likelihood that each activity's duration / cost will be somewhere on the continuum between the three estimates. The response to the above questions cannot be a definitive answer in the form of a fixed date or amount. A mature project manager would prefer to state the estimated date or amount along with the associated confidence or accuracy levels.

Example response: "based on the individual activity duration estimates, there is X% chance that the project will be complete on or before date Y".

So the challenge the project manager has is how to make deterministic predictions on time & cost after factoring variations in time & cost for the individual activities on the project schedule?

The Monte Carlo method is one of many methods for analyzing uncertainty propagation, where the goal is to determine how random variation; lack of knowledge, or error affects the sensitivity, performance, or reliability of the schedule that is being modelled. Monte Carlo simulation is categorized as a sampling method because the inputs are randomly generated from probability distributions to simulate the process of sampling from an actual population. So, we try to choose a distribution for the inputs that most closely matches data we already have, or best represents our current state of knowledge.

The data generated from the simulation can be represented as probability distributions (or histograms) or converted to error bars, reliability predictions, tolerance zones, and confidence intervals

Figure:4 illustrates the output from a simulation. It can be inferred from the illustration that the project has 80% chance to complete on 21st Dec.

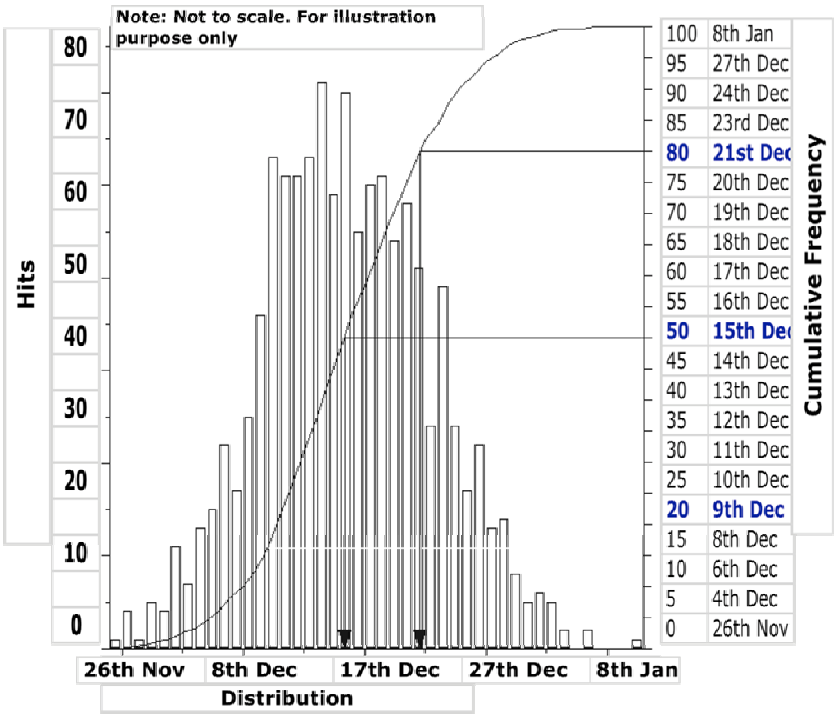


**Figure:4** Simulation output used to draw project schedule inferences

Monte Carlo methods are useful for modelling phenomena with significant uncertainty in inputs, such as the calculation of risk in project. It is a widely successful method in risk analysis when compared with alternative methods or human intuition. Compared to human intuition, Monte Carlo simulations can better predict risks to schedule & cost when applied in projects.

So what are the key steps to carry out a Monte Carlo?

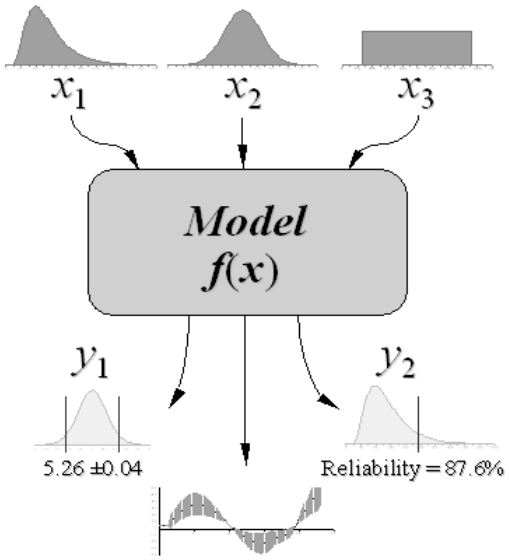


**Figure: 5** Sample Steps to carry out Monte Carlo analysis

**Step 1:** Create a parametric model, y = f(x1, x2, ..., xq).

**The question would be project completion date & cost? The model answering the question would be the network diagram, expected value of key risks, 3-point estimates.**

**Step 2:** Generate a set of random inputs, xi1, xi2, ..., xiq.

**Associate the activity estimates in step 1 to a probability distribution (such as Normal, Beta, Triangular, etc.);**

**Step 3:** Evaluate the model and store the results as yi.

**This are the possible outcomes under the scenarios simulated**

**Step 4:** Repeat steps 2 and 3 for i = 1 to n.

**Perform at least 1000 iterations to get a good representation**

**Step 5:** Analyze the results using histograms, summary statistics, confidence intervals, etc.

**Allows the project manager to predict estimates for project time & cost based on a proven deterministic model.**

## 1.8 Scenario 3: Building an Early Warning System for Project Monitoring & Control

During project planning the various statistical techniques can help develop more accurate estimates.

As additional information becomes available during execution, same should be processed through the monitoring & control processes to improve project performance management. A project early warning system based on statistical techniques can help the project manager to respond to project risks. It also improves the stakeholder communication.

Incorporating the relevant efficiency & effectiveness project performance metrics on a dashboard with appropriate threshold definition for Red, Amber, Green (RAG) statuses can demonstrate mature project management without getting lost in the maze of statistical jargons & information overload.

## 1.9 Impact of assumptions on the inferences derived using statistical techniques

In uncertainty and sensitivity analysis there is a crucial trade off between how meticulous an analyst is in exploring the input assumptions and how wide the resulting inference may be. The point is illustrated by:

*"I have proposed a form of organized sensitivity analysis that I call 'global sensitivity analysis' in which a neighbourhood of alternative assumptions is selected and the corresponding interval of inferences is identified. Conclusions are judged to be sturdy only if the neighbourhood of assumptions is wide enough to be credible and the corresponding interval of inferences is narrow enough to be useful."*

Edward E. Leamer (econometrician)

## 1.10 Conclusion

Decision theory, expected value, earned value management, decision &probability trees, probability distributions, sampling, control charts, quality management tools, simulation, sensitivity analysis and other statistical techniques can be used to improve project performance predictability.

Stakeholder management can be significantly improved by increased accuracy in communicating project estimates (during planning) & project performance (during monitoring).

## 1.11 Author's Profiles

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