Integrating Monte Carlo Simulation and MS Project 2000 for Project Time Analysis

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Abstract

Time risk management is one of the important aspects in project management. This is because typical projects often overrun their estimates. PERT methodology is often employed to compute the project completion time probability profile. This methodology, however, does not cater for near critical activities. Monte Carlo Simulation has been suggested in the literature to overcome this shortcoming (Van Slyke, 1963, p.839). However this suggestion has not been much employed in project management so far, mainly because of the high volume of computation required and the limited availability of computation facilities in the past. With the widespread use of PC's at present, one may readily deploy the Monte Carlo Simulation technique and integrate it with present project management software, such as Microsoft Project 2000 (MSP2000), to enhance the quality of project planning and control. This may be achieved by writing appropriate macros and incorporate it within MSP2000. This is what is put forward in this paper. A macro has been developed in Visual Basic for MSP2000. The capabilities of the software hence developed are described with the example of a construction project called "Clever Clogs Project".

Introduction

Typical projects often overrun their time estimates. Overruns are common on government and commercial projects, even when changes in the design are taken into account (Hulett, 1999, p.1). One reason this happens is because time estimating traditionally fails to take into account the risk that the work will actually time more (or less) than provided by even the most competent estimates.

Future estimates are not facts but statements of probability about how things will turn out. Because estimates are probabilistic assessments, times may actually be higher or lower than estimated, even by seasoned professional estimators. The reasons are often causes that are outside the control of the project manager, but may also be endemic to

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the estimating process, the project strategy or the corporate culture within the project contractor.

Time risk analysis methods are required to provide more accurate estimates of total project time. PERT methodology is often employed to compute the project completion time probability profile. This methodology, however, do not cater for near critical activities. Monte Carlo Simulation has been suggested in the literature to overcome this shortcoming (Van Slyke, 1963, p.839). Monte Carlo Simulation helps to gain better information that traditional methods not using simulation could not provide.

Monte Carlo Simulation has not been, however, much employed in project management so far, mainly because of the high volume of computation required and the limited availability of computation facilities in the past. With the widespread use of PC's at present, one may readily deploy the Monte Carlo Simulation technique and integrate it with present project management software, such as MSP2000, to enhance the quality of project planning and control, as proposed in this paper.

Objectives of a Project Time Risk Analysis

Time risk analysis using Monte Carlo Simulation can answer some questions that the traditional estimating methods not using simulation cannot. Included are:

- **"What is the most likely time?"** The traditional methods assume that this is the baseline time computed by summing the estimates of time for the project elements. But this is not necessary the case.
- **"How likely is the baseline estimate to be overrun?"** Traditional methods do not accurately address this problem.
- **"What is the time risk exposure?"** This is also the answer to the question; "How much contingency do we need on this project?"
- **"Where is the risk in this project?"** This is the same as: "Which time elements cause the most need for contingency?" Risk analysis principles can be used to answer this question.

Time Risk Analysis Using Monte Carlo Simulation within MSP2000

To show how a time risk analysis is done using Monte Carlo Simulation within MSP2000, we first take a look at a traditional estimate for an exemplar construction project called “Clever Clogs Project”. The traditional estimate has been constructed. The table below shows the summary of the Clever Clogs project time estimates.

Table 1 gives a time estimate of 493.83 days. How likely is it that this project will be completed for this time duration? In fact, is 493.83 days indeed the most likely estimate? To answer these questions, we need to examine the uncertainties in the baseline estimates.

Table 1: Traditional Time Estimates for Clever Clogs Project

ID	WBS	Task Name	Duration	Start	Finish
1	***1***	***Clever Clogs Projects***	**493.83d**	***05/10/00***	***03/20/02***
2	1.1	Start	0d	05/10/00	05/10/00
3	1.2	Eviction of Squatters	25d	05/10/00	06/13/00
4	1.3	Designing	30.33d	05/24/00	07/04/00
5	1.4	Land Preparation	43.5d	06/14/00	08/10/00
10	1.5	Foundation Work	90.83d	08/11/00	12/14/00
15	1.6	Structural Work	73.5d	12/15/00	03/27/01
20	1.7	Masonry Work	116.33d	03/28/01	08/29/01
30	1.8	Utilities Installation	15d	08/30/01	09/19/01
37	1.9	Finishing Works	124.67d	08/30/01	02/20/02
46	1.10	Facilities	8d	02/21/02	03/04/02
51	1.11	Yard and Gardens	20d	02/21/02	03/20/02
57	1.12	Finish	0d	03/20/02	03/20/02

Time Risk Analysis Data Requirements

Time risk analysis would certainly need more data. Gathering these data can be a difficult task but the rewards are valuable. A risk analyst may be assigned with the task of gathering the necessary data.

To follow along the case of Clever Clog, the risk analyst has to choose well various project experts who should be interviewed. These experts will probably include the project team and the team leader. They may also include experienced project professionals from the company who are not currently assigned to this project. Outside experts may sometimes be included too, although this is rare except in the cases of public projects.

The risk analyst may use the opinions of the experts to determine the type of probability distributions pertaining to the project activity times and the distributions parameters. The types of distributions proposed in the developed software include "normal", "beta", "triangular", "uniform" and "exponential". The parameters include, "mean", "standard deviation", "optimistic times", "pessimistic times", "most likely times", etc.

The rationale for the distributions and the parameters is explored and recorded in the notes of the meeting. The rationale is most important because it points to the risk mitigation, which is also discussed in the risk interview.

Suppose that this interview has occurred and the following estimates are secured.

Table 2: The Results of Interview with Experts

ID	WBS	Task Name	Dist.	Min	Max	M. Likely
1	***1***	***Clever Clogs Projects***	***Beta***	***391***	***633***	***486***
2	1.1	Start	Beta	0	0	0
3	1.2	Eviction of Squatters	Beta	15	35	25
4	1.3	Designing	Beta	27	35	30
5	1.4	Land Preparation	Beta	36	57	42
10	1.5	Foundation Work	Beta	74	111	90
15	1.6	Structural Work	Beta	97	131	110
20	1.7	Masonry Work	Beta	128	224	160
30	1.8	Utilities Installation	Beta	39	70	54
37	1.9	Finishing Works	Beta	135	196	165
46	1.10	Facilities	Beta	12	28	20
51	1.11	Yard and Gardens	Beta	36	59	47
57	1.12	Finish	Beta	0	0	0

The "min" and "max" ranges are not often symmetrical about the estimates. In fact, they often exhibit a greater likelihood for over-runs than for under-runs. This is in part because there is a natural barrier (zero) to the lowest time possible and there are many ways the project can run into trouble on the high side.

In the example above, it is assumed that the baseline estimate is the "most likely" time. In fact, many estimates are not the most likely when the estimators are questioned closely. Sometimes, the risk interview turns up some baseline estimates that should be changed in order to represent the most likely time. This is one clear benefit of a risk interview, or indeed of any honest and careful scrubbing of the baseline. But, in this example it will be assumed that the baseline was carefully estimated without being "shaded" or biased in any way, and that new information has been recently incorporated in it.

Monte Carlo Simulation method is simple to describe. Yet, the software of Microsoft Project 2000 (Microsoft Company, 2000) does not include Monte Carlo Simulation capabilities. A macro was developed in Visual Basic to augment the MSP2000 package, to enable it to simulate the activities duration times.

Simulating the Time Risk Model – Simulation Results

Using the time ranges presented in Table 2 and assuming beta distribution for all activities in the Clever Clogs project, Monte Carlo simulation was run using the Monte Carlo Macro v.1.0 developed in this study. The Monte Carlo simulation was run for many iterations. For each iteration, the simulation program selected a time at random, from the probability distribution specified by the analyst for each of the uncertain time elements.

A question that needs to be addressed in similar simulation studies is: "How many iterations is enough?" The answer would depend on the potential use of the information. When the main objective of the analysis is to get a mere estimate of the most likely time, less iterations are needed. If accuracy in the tails of the resultant distribution is important, more iterations will be required. To illustrate this fact, four sets of iterations i.e. 100, 500, 1000 and 5000 were used. Figure 1 and Table 3 show the sensitivity and normality of each case.

Table 3: The Results of Sensitivity and Normality Analysis

No	Iteration	Duration Mean	Normality
1	100	492.890	Very Low
2	500	493.290	Low
3	1000	494.151	Medium
4	5000	494.007	Well

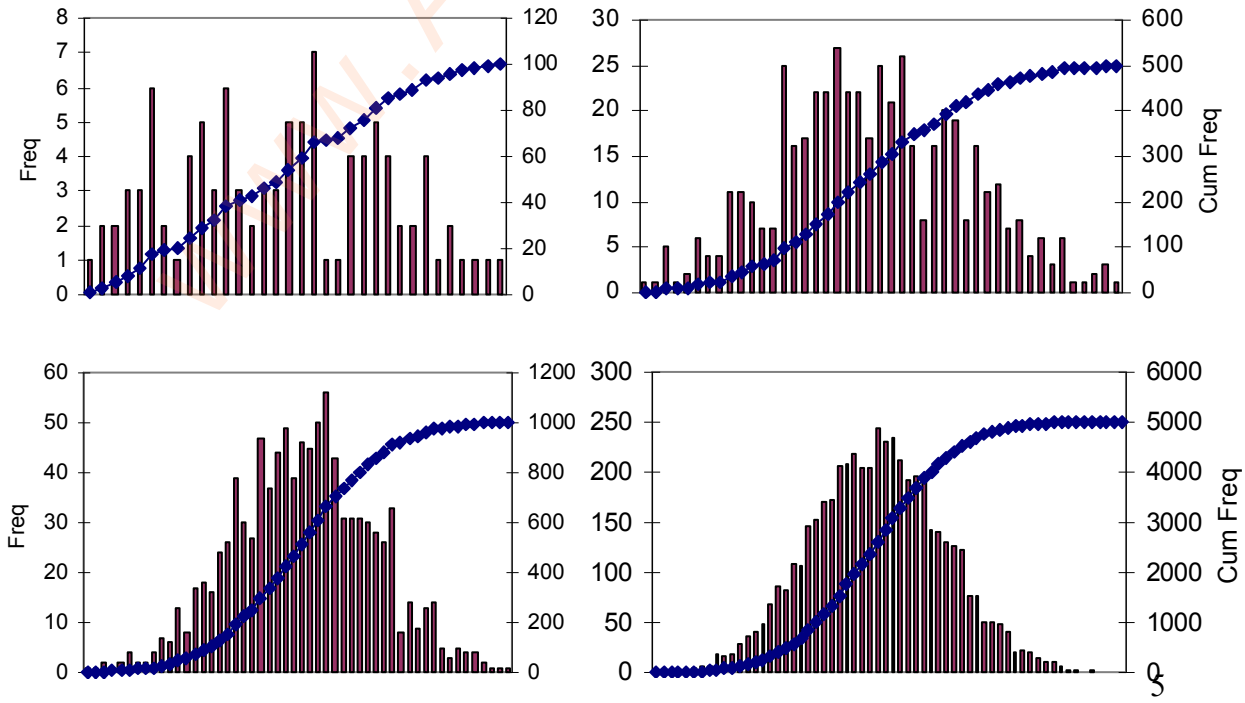

Figure 1: The Project Duration Probability Diagram for Each Number of Iteration

In order to have a more accurate distribution, the simulation with 5000 iterations was selected in this study. The result is shown in figure 2.

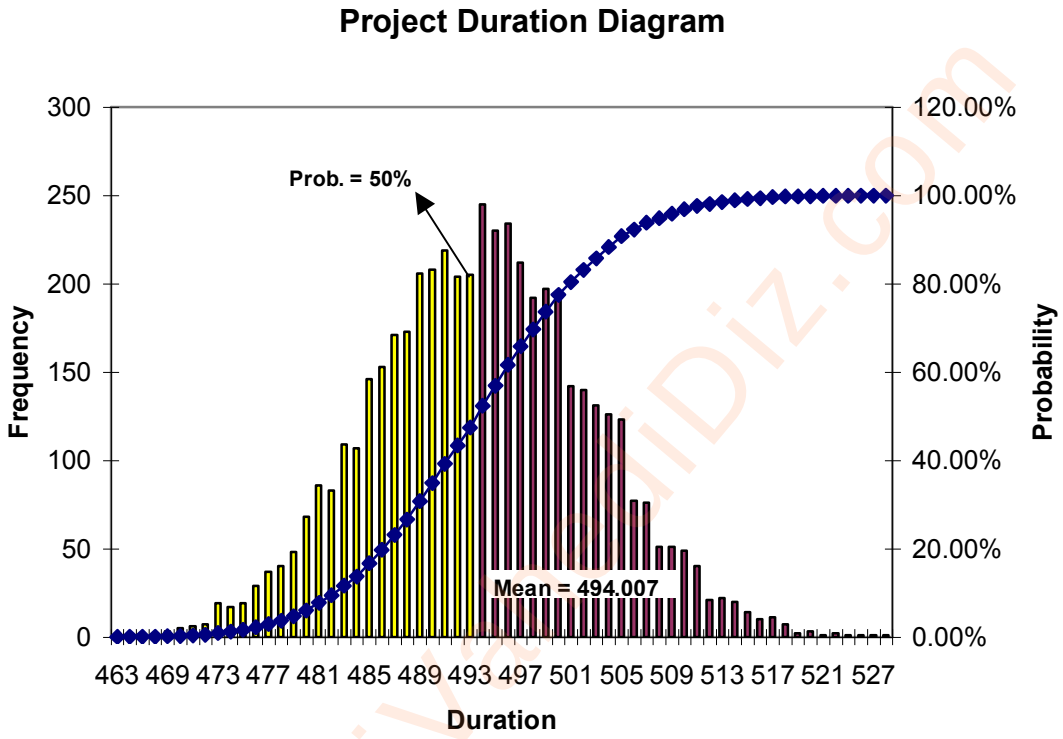

Figure 2: The Project Duration Probability Diagram for 5000 Iterations

In similar cases, the project manager may ask; "What is my exposure here?" This question expresses the feeling that if the project were 90% likely to overrun by a day, it does not matter, but if it were even 30% likely to overrun by 600 days that would be a real problem.

Monte Carlo Simulation Macro v.1.0 gives the answer in the cumulative likelihood distribution. This is just the distribution shown above cumulated from left to right starting at 0 likelihood of time and cumulating to 100% (see figure 2). This cumulative chart shows a vital result to the project manager. Suppose that the company is conservative, and will only bid for a project that has at most a 15% likelihood of overrunning. Should they get the bid, this level will be an acceptable risk. The chart shows that the amount bid should be 503 days. Another way to look at this result is that a contingency of only about 10 days would be necessary to provide the comfortable level of the company.

Critical Index

One question that needs to be addressed is: "What is the risk of each activity in the project?" The answer is the "critical index".

Critical indexing is the implementation of the Monte Carlo Simulation technique to solve for the problem of uncertainty in times of a predetermined network. The problem is to find the critical path of a network where times of the events are random, under a certain probability function. So critical indexing can be defined as determining the importance of an activity in the completion of a network, and the critical index of an event is defined as the probability that the activity belongs to a critical path (El-Shayeb, 1996, pp. 43).

Activities with the highest critical index would be subjected to the most managerial attention, since it has a high probability of belonging to the critical path and so high probability to delay the network.

Determination of critical indices for activities in a network could be achieved using Monte Carlo Simulation. The capability to compute critical indices has been incorporated into the Monte Carlo Simulation Macro v. 1.0, proposed in this paper. The simulation result of the critical indices for the Clever Clogs Project is shown in table 4.

Two important results can be observed:

First. The activities with 100% critical index are very important and have high probability to delay the project. The project manager should also focus on the activities that have critical index higher than zero, since they may probably become critical during the course of the project.

Second. If one activity had low critical index but long duration time, it should be taken more into account. It means that if the activity was 90% likely to be critical by a day, it may not matter. But if it was even 30% likely to be critical by 60 days, that would be a real critical activity.

Summary

A macro was developed in this paper using Visual Basic and incorporated into the MS Project 2000 software to enable it to do time risk analysis using Monte Carlo Simulation.

PERT methodology is often employed in project management to compute the probability profile of the project completion time. Yet this methodology is deficient in that it does not cater for the near critical activities. Simulation has been often suggested as the way to alleviate this deficiency. Yet this has not been deployed much in practice, presumably because of the computation burden. In particular Microsoft Project 2000 does not currently have this capability.

The purpose of time risk analysis is to assist the project manager by indicating the magnitude of the problems and high light the areas that needs more attention. This can be achieved by developing the concept of critical index. This paper has demonstrated how

this can accomplished by integrating the Monte Carlo Simulation and the Microsoft Project 2000 software.

The integrated software developed in this study was used on an exemplar case, a construction company to demonstrate its capability.

Table 4: The Critical Indices for A Part of Clever Clogs Project Activities

ID	WBS	Task Name	Exp. Dur.	Critical Index
1	***1***	***Clever Clogs Projects***	***502.49***	
2	1.1	Start	0.00	100%
3	1.2	Eviction of Squatters	25.10	100%
4	1.3	Designing	30.65	**9.18%**
5	1.4	Land Preparation	45.29	100%
6	1.4.1	Demolishing	20.68	**90.82%**
7	1.4.2	Soil removal	16.00	100%
8	1.4.3	Site preparation	8.30	100%
9	1.4.4	End of land preparation	0.00	100%
10	1.5	Foundation Work	91.66	100%
30	1.8	Utilities Installation	15.07	0%
31	1.8.1	Electrical	14.99	0%
35	1.8.5	Lift	9.36	0%
36	1.8.6	End of Utilities Installation	0.00	0%
37	1.9	Finishing Works	125.27	100%
38	1.9.1	Plastering	39.33	100%
39	1.9.2	Marble works	29.32	100%
40	1.9.3	Door installation	20.03	**51.02%**
41	1.9.4	Window installation	19.99	**48.98%**
42	1.9.5	Glass works	11.01	100%
43	1.9.6	Painting	21.00	**1.92%**
44	1.9.7	Decorative Works	24.68	**98.08%**
49	1.10.3	Squash yard	5.34	0%
50	1.10.4	End of Facilities	0.00	0%
51	1.11	Yard and Gardens	19.97	100%
57	1.12	Finish	0.00	100%

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