PERT & MC Simulation based Risk Management

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***Abstract*—In a software project, predicting the likelihood of duration may play a key role towards project success. This paper analyzed the traditional probability analysis method for duration risk in program evaluation and review technique (PERT). On basis of that it simulates the project's duration and analyzes the risk by Monte Carlo simulation method. The result shows that the Monte Carlo Simulation method is convenient, effective and efficient. It supports the decider powerfully.This paper describes a simulation based risk management tool which helps manager to identify high risk areas of software process. The usual PERT procedure may lead to overly optimistic results as many pass which are not critical but slightly shorter than critical on the basis of estimated activity duration or average durations. In order to overcome this problem and be more reasonable, the Monte Carlo Simulation approach has been used and designed by generating random samples from a specific probability distribution associated with that particular activity of SPM.**

Keywords- SPM; Probability Distribution; PERT; Monte Carlo Simulation

I. INTRODUCTION

Planning and decision making are the basic duties of a project manager and without them it is impossible to reach project goals [1].

Successful project management is intricate and multifaceted [11]. Tasks must be assigned to resources with different characteristics, taking complex dependencies, constraints and uncertainties into consideration, attempting to meet goals related to costs and time [2]. To design a SPM system is to simulate the application of a project plan to see how uncertainties about task duration, etc., affect the outcome. Schedules are essential to the successful execution of projects. It is widely accepted that project schedule plays a key role in project management due to its influence on project success [3] [4]. The PERT (Program Evaluation and Review Technique) is widely used as a tool for managing large-scale projects. It was introduced in the 1950s to estimate the time required for a given task [6].

Monte Carlo analysis is a statistical technique that could become increasingly important as a means for risk assessors to evaluate the uncertainty. Although Monte Carlo simulation has been used since the 1940s, more powerful desktop computers have made it accessible and attractive for many new applications. In [1], Monte Carlo simulation analysis is implemented as an integrated tool to reach the project goals, analyzing and investigating a variety of uncertainty permutations simultaneously. PAN Chun-guang [7] builds a programming model to find the critical path in fuzzy planning network and the model can be transformed into a multiple objective linear programming. Marta Schuhmacher [8] uses Monte Carlo simulations techniques in risk assessment and the result shows that the estimate of the coefficient of relative risk aversion tends to have a negative bias.

Aim of schedule risk analysis is to decrease the time delivery [9]. A missed schedule can reduce market impact, create customer dissatisfaction and can raise internal costs also.

Most of the major issues of concern to a planner and project manager are addressed by a variety of computer based tools. Depending on the budget available, it is possible to choose a tool with the sophistication and functionality to suit your needs. However, in one area both the standard techniques and the tools still provide little if any support. Schedule risk modelling need not be unduly complex or time consuming. Probabilistic representations allow for much more realistic predictions than are possible by conventional methods, so they make it possible for plans to be realistic without a large amount of detail. Risk modelling enables planners to give a complete view of a project, from the top down, to whatever level of detail is appropriate.

II. TRADITIONAL RISK ANALYSIS METHOD

Time risk means the possibility and loss of incompletion in the total stipulated duration limit. According to the definition of time risk, the mathematical expression of time risk can be defined as follows:

$$R=F(P_F, C) \quad (1)$$

In which R is the time risk, P_F is probability of incompletion in the total stipulated duration limit, and C is loss for incompletion.

When the total stipulated time limit is Ts, the completion probability can be defined by formula (2).

$$P(T<T_S) = \int F(t).\, dt \quad (2)$$

in which F(t) is the probability density function of project's total duration[10].

PERT assumes that the duration of each activity is a random variable and it obeys Beta distribution [4, 6]

For each activity i, we must estimate its optimistic duration a_i, pessimistic duration b_i, and most likely duration m_i. Then we can calculate the mean μ_i and the variance σ_i^2 of duration for each activity by the following formula

$$\mu_i = (a_i+4m_i+b_i)/6 \qquad \sigma_i^2=(b_i-a_i)^2/36 \qquad (3)$$

According to the central limit theorem, the sum of independent identically distributed random variables is approximately distributed normally. That means the project duration obeys normal distribution

III. PROPOSED SIMULATION METHOD

A. *Generation of pseudorandom samples*

In order to simulate the schedule risk, we must take samples for the random variable. The most commonly used technique to generate a sequence of pseudorandom numbers is called linear congruential method [10]. Linear congruential method for generating n random numbers is based on the fundamental congruence relationship, which can be expressed as following formula.

$$X_{n+1}= (rx_n+c) \text{ (mod s)}, n=0, 1, 2\ldots.. \qquad (4)$$

in which r is the multiplier, c is the increment, x_0 is the seed, and s is an integer-valued modulus..

B. *Process of simulation*

As far as risk analysis is concerned, Monte Carlo simulation is performed in the following steps:

Step-1: Determine the distribution function for each activity of the software project.In this paper we select Beta distribution as the distribution of each activity

Step-2: Estimate the optimistic duration a, pessimistic duration b, and most likely duration m of each activity

Step-3: Generation of pseudorandom numbers r1, r2 € [0, 1].

Step-4:Generate activity duration samples using Beta Distribution

[Calculate g $(a_k+ (b_k-a_k)*r1) = (r1)^{k1-1}*(1-r1)^{k2-1}/ (b_k-a_k)$ where k1=4, k2=4.

Calculate g $(m_k) = (m_k-a_k)^{k1-1}*(b_k-m_k)^{k2-1}/ (b_k-a_k)^{(k1+k2-1)}$

If g $(a_k+ (b_k-a_k)*r1)/$ g $(m_k) >= r2$ then

TIME (K) = $a_k+ (b_k-a_k)*r1 \forall$ K =1, 2...N Else go to step 3]

Step-5: Traverse the network for forward pass

Step-6: Traverse the network for backward pass

Step-7: Compute the risk index counter for each activity.

Step-8: Print risk indices of each activity

IV. RESULTS OF PROPOSED APPROACH

The data of each activity's estimated duration such as optimistic duration O, pessimistic duration P, and most likely duration M of a certain project are given in TABLE.I

TABLE I. Activity's Estimated Duration

Activity(i,j)	Estimated Duration (days)		
	O	**M**	**P**
(1,2)	7	15	35
(1,3)	2	5	8
(2,4)	4	7	15
(2,5)	3	7	15
(2,6)	7	15	30
(3,7)	5	10	25
(4,8)	1	3	10
(4.9)	1	2	3
(4,10)	2	3	3
(5,11)	1	2	5
(5,12)	10	14	40
(6,16)	0	0	0
(7,16)	0	0	0
(10,13)	1	3	10
(11,14)	10	15	30
(12,15)	1	4	10
(14,17)	1	2	5
(15,16)	7	20	40
(16,17)	1	3	5
(8,17)	15	30	100
(9,17)	10	20	50
(13,17)	7	10	15
(17,18)	6	20	30
(18,19)	2	7	15
(19,20)	2	7	20

The model simulated, tabulated, and plotted the frequency and distribution functions for, 1000 simulated project schedule outcomes. Table II shows the risk (criticality) index values for various activities.

TABLE II: Risk Indices of Activities

Activities	Risk Index	Activities	Risk Index
1	**1**	14	0.003
2	0	15	0.019
3	0.148	**16**	**0.859**
4	**0.876**	17	0.019
5	0	**18**	**0.859**
6	0	**19**	**0.859**
7	0.133	20	0.133
8	0.016	21	0.016
9	0.003	22	0.003
10	0.019	**23**	**1**
11	**0.859**	**24**	**1**
12	0	**25**	**1**
13	0		

Fig. 1 presents the result of Table II in graphical form

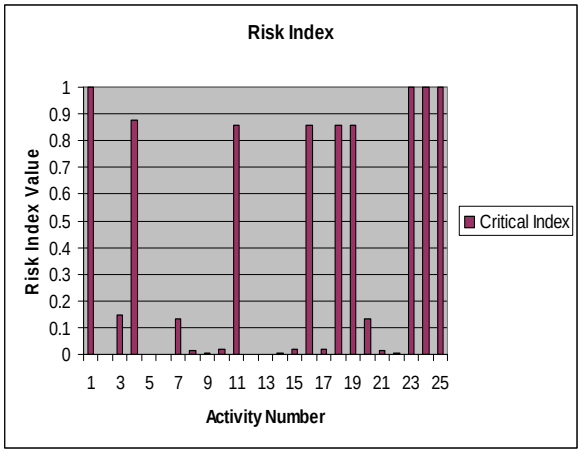

Fig.1: Risk Index Chart

A diagram based on the frequency data is generated showing the frequency of total duration values among the 1000 simulations within the specified intervals (bars in the figure).The duration 89 days occurs for the maximum times during simulation experiment Fig.2 shows the simulated frequency distribution chart for the software project being simulated.

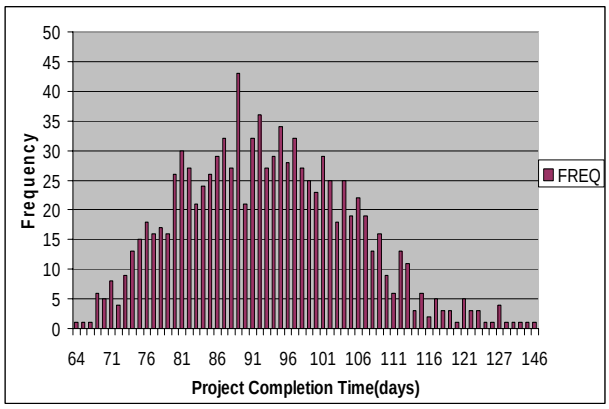

Fig.2: Frequency Distribution Chart

V. CONCLUSION

In today's scenario project management is paid more attention. Managing risks in software projects is recognized as a very important process in order to achieve project objectives in terms of time. The motivation for wanting to incorporate simulation into Schedule risk Analysis is clear as finding critical activities with simulated data yields fruitful information such as estimation of software project/activity completion time.

Monte Carlo method was used to simulate the duration for each activity and the overall project to accurately determine the completion probability of the project under considering of the changeability and randomness of duration for each activity. It helps decision makers easily make control with duration risk of project and make true decision

The research undertaken in this paper concluded that greater the criticality index value associated with an activity, greater is the risk involved, and will provide effective decision making during the development phase and planning schedule estimation

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