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FACULTY OF ELECTRICAL ENGINEERING

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UNIVERSITY „GOCE DELCHEV” - SHTIP
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PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the International Conference ***Electrical Engineering, Informatics, Machinery and Automation - Technical Sciences applied in Economy, Education and Industry-ETIMA.***
ETIMA has a goal to gather the scientists, professors, experts and professionals from the field of technical sciences in one place as a forum for exchange of ideas, to strengthen the multidisciplinary research and cooperation and to promote the achievements of technology and its impact on every aspect of living. We hope that this conference will continue to be a venue for presenting the latest research results and developments on the field of technology.
Conference ETIMA was held as online conference where contributed more than sixty colleagues, from six different countries with forty papers.
We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA'21 by presenting the results of their current research activities and by launching the new ideas through many fruitful discussions.
We invite you and your colleagues also to attend ETIMA Conference in the future. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information in direct contact, as well as to enjoy the social events together.

The Organizing Committee of the Conference

ПРЕДГОВОР

Меѓународната конференција ***Електротехника, Технологија, Информатика, Машинство и Автоматика-технички науки во служба на економија, образование и индустрија-ЕТИМА*** е организирана од страна на Електротехничкиот факултет при Универзитетот Гоце Делчев.
ЕТИМА има за цел да ги собере на едно место научниците, професорите, експертите и професионалците од полето на техничките науки и да претставува форум за размена на идеи, да го зајканува мултидисциплинарното истражување и соработка и да ги промовира технолошките достигнувања и нивното влијание врз секој аспект од живеењето. Се надеваме дека оваа конференција ќе продолжи да биде настан на кој ќе се презентираат најновите резултати од истражувањата и развојот на полето на технологијата.
Конференцијата ЕТИМА се одржа online и на неа дадоа свој допринос повеќе од шеесет автори од шест различни земји со четириесет труда.
Сакаме да ја искажеме нашата благодарност до сите колеги кои допринесоа за успехот на ЕТИМА'21 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Ве покануваме Вие и Вашите колеги да земете учество на ЕТИМА и во иднина. Веруваме дека следниот пат ќе имаме можност да се сретнеме, да размениме идеи, знаење и корисни информации во директен контакт, но исто така да уживаме заедно и во друштвените настани.

Организационен одбор на конференцијата

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COMPARISON OF PERT AND MONTE CARLO SIMULATION

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Abstract

Risk management is critical issue for successful competition of any project. In order to complete a project within predefined schedule it is crucial to estimate the probability of project completion precisely. The aim of project management when dealing with large and complex projects is to identify the critical path and one or several subcritical paths. In this paper a comparison between two most widely used project planning and scheduling techniques PERT (Program Evaluation and Review Technique) and Monte Carlo simulation is made. PERT considers the uncertainties in activity duration by considering three estimates of time, while in Monte Carlo simulations the distribution for activity duration can be uniformed, triangle, normal etc. The analysis made in this paper is based on same project using classical PERT and Monte Carlo simulation with uniform distribution of time activity. The model used in this paper is developed in C++ programming language.

Key words

PERT, Monte Carlo simulation, project scheduling, activity duration.

Introduction

A typical modern- day project requires coordination of numerous complex activities, so the project risk and uncertainty have to be considered. Project management consists of planning, designing and implementation a set of activities that needed to be completed in order project to end successfully. The main aim in project management is identification of the critical path of the project. The critical path is defined as longest path through the project network so that the project is completed in shortest possible duration. If any activity on the critical path is delayed, the completion of the project will be delayed. The most popular technique for identification of the critical path used in project management is Project Evaluation and Review Technique (PERT). PERT is a network based technique developed by US Navy for the POLARIS Missile Program, [1]. PERT overcomes the disadvantages of Critical Path Method (CPM) so that, activity duration is a random variable calculated by three points estimation as an average heavily weighted toward the most like time.

When the project is large and complex, the project manager has to identify one critical path and several subcritical paths. The subcritical path is a set of activities that are almost critical or are at risk of becoming critical if delayed past their expected competition time. This rises the project sensitivity and the risk of delaying the project. In order to overcome the disadvantages of PERT [2-3], Monte Carlo simulations are used. Monte Carlo simulation identifies not only the critical path, but subcritical paths that may become critical.

This paper is organized as follow. In section 3 overview of PERT approach is given, while in section 4 Monte Carlo simulations are represented. The used methodology is given in Sector 5. In Sector 6 numerical illustration of a given project is represented. Sector 7 concludes this paper.

1. Project Evaluation and Review Technique (PERT)

In practice, it is not always possible to determine the exact duration of the activities, so the projects include variability in time required to complete the activity due to various factors such as lack of experience, equipment breakdown, late delivery, unpredictable weather conditions and etc. Therefore, PERT uses three point estimates to determine the average weighted duration of the activities: optimistic time (a), most likely time (m) and pessimistic time (b) as represented on Figure 1. All the activity times are random independent variables having beta distribution with probability density function:

$$f(x) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \frac{(x-a)^{\alpha-1}(b-x)^{\beta-1}}{(b-a)^{\alpha+\beta-1}} \qquad (1)$$

Where α and β are shape parameters, $a < x < b$ and $\alpha, \beta > 0$. $\Gamma(\cdot)$ is gamma function.

The expected time (mean) to complete each activity is calculated as:

$$t_e = \frac{0+4m+b}{6} \qquad (2)$$

With variance $\sigma_x^2 = (\frac{b-a}{6})^2$.

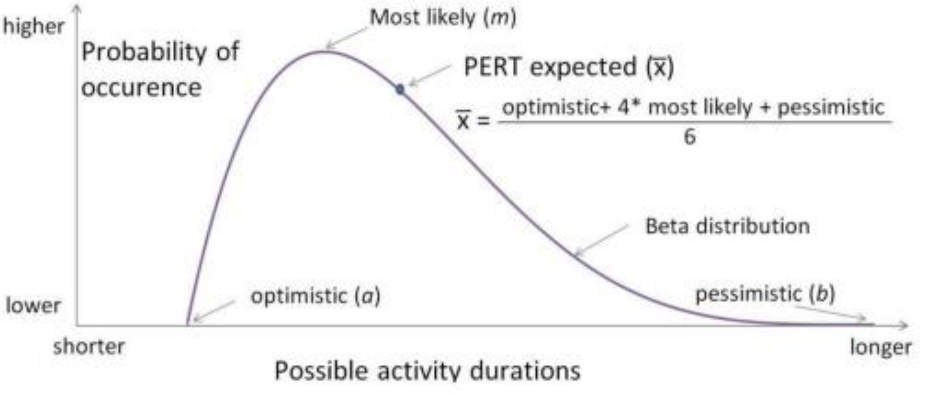

Fig. 1. Density function of PERT- beta distribution

According to central limit theorem if the network is large enough than the project duration follows a normal distribution with mean μ and variance of the distribution of the project duration defined as:

$$\sigma^2 = \sum_x \sigma_x^2 \qquad (3)$$

Where x represents the activities on the critical path. Knowing the expected project duration and standard deviation of the critical path, the probability of completing the project earlier or later than μ can be calculated using normal distribution as:

$$Z = \frac{T-\mu}{\sigma} \qquad (4)$$

Where T is desired completion time of the project.

2. Project Evaluation and Review Technique (PERT)

The term Monte Carlo was first introduced by Von Neumann and Ulam during World War II, [4], as a code for the secret development of Los Alamos atomic bomb that included behavior simulation of accidental neutron diffusion. Today, Monte Carlo method is one of the most commonly used powerful tool for analysis of complex projects. This method initially used random or pseudo random numbers with uniform distribution in the interval [0;1].

The PERT method discovers one critical path and other possible subcritical paths are ignored. If the duration of the critical path is around its most likely time completion time and if the subcritical path ends around its optimistic time, the project will be delayed. That's the main reason why techniques like Monte Carlo are used. Monte Carlo simulations are used to calculate the entire network diagram and obtain one critical path and possible subcritical paths.

In this paper, the simulations are performed with a uniform distribution (figure 2) where the most likely time to complete the activity is a random number in range between the optimistic and pessimistic time. The probability density function of a uniform distribution is defined as:

$$f(x) = \begin{cases} \dfrac{1}{b-a}, x \in (a,b) \\ 0, x \notin (a,b) \end{cases} \tag{5}$$

With cumulative distribution function defined as:

$$F(x) = \begin{cases} \dfrac{x-a}{b-a}, x \in (a,b) \\ 1, x > b \\ 0, x < 0 \end{cases} \tag{6}$$

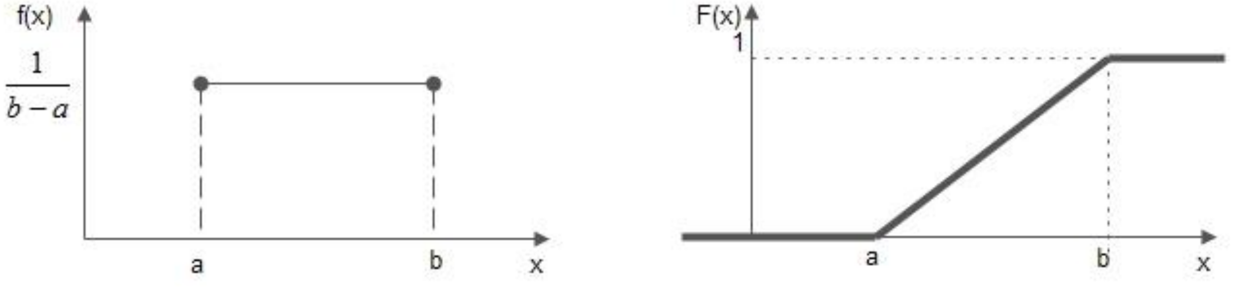

Fig 2. Probability density function and cumulative distribution function of uniform distribution

3. Methodology

A network diagram is formed for the given project. First, the PERT is applied to the project to evaluate the probability of project completion for a given time unit (day, mouths). The results obtained identifies only one critical path. After that, Monte Carlo simulations are performed on the same project in order to obtain probability of project competition. Results from these simulations identifies same critical path and one or more subcritical path with percentage of occurrence. At the end, a comparison of PERT and Monte Carlo simulations is made.

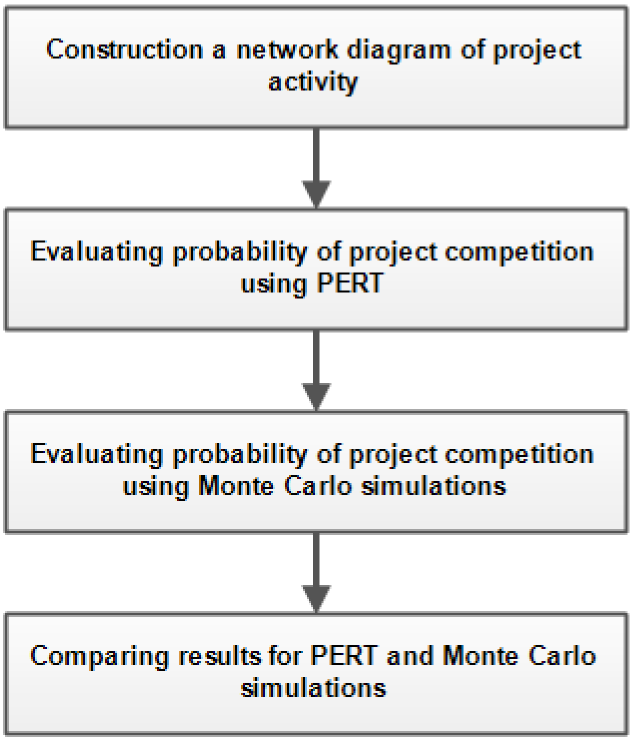

Fig 3. Methodology

4. Numerical illustration

In this paper the project [5] given with data represented in Table I is analyzed. The starting activity of the project is denoted as activity1 and end activity is denoted as activity 7. Project due date is set to 37 time units. The network diagram of this project is given in Figure 5.

Table 1 Time estimates for project activities

Activity	(a,m,b)	Activity	(a,m,b)
(1-2)	(5,6,8)	(3-6)	(3,4,5)
(1-4)	(1,3,4)	(4-6)	(4,8,10)
(1-5)	(2,4,5)	(4-7)	(5,6,8)
(2-3)	(4,5,6)	(5-6)	(9,10,15)
(2-5)	(7,8,10)	(5-7)	(4,6,8)
(2-6)	(8,9,13)	(6-7)	(3,4,5)
(3-4)	(5,9,19)		

The code for PERT calculations is developed in Program Language C++. After executing the program, the differences of the output from the procedures forward and backward pass gives the floating time for every project activity. If the activity has zero floating time any delays in completing this activity will delay project completion, so thus this activity is part of the critical path.

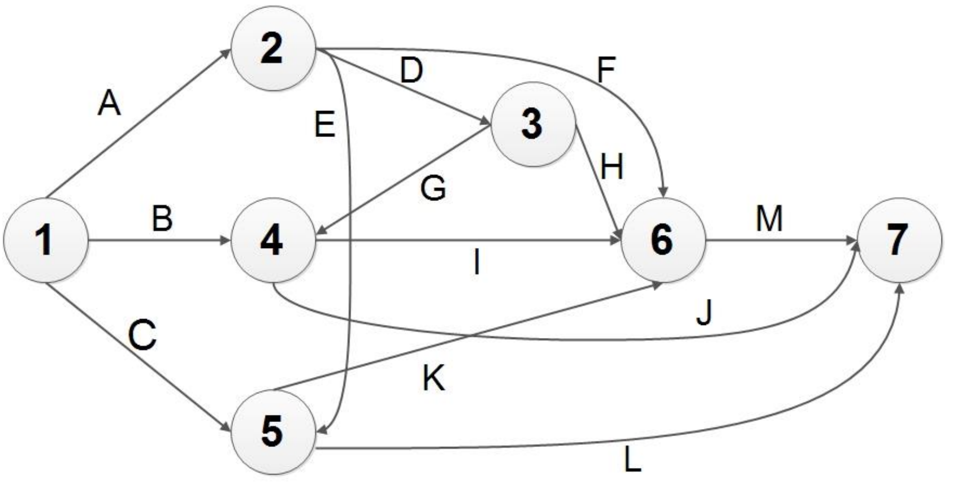

Fig. 4. Network diagram

Table 2 Floating times for project activities

Activity	(i,j)	Floating time S_{ij}	t_e	σ_x^2
A	(1-2)	0	6.17	0.25
B	(1-4)	18.33	2.83	0.25
C	(1-5)	14.34	3.83	0.25
D	(2-3)	0	5.00	0.11
E	(2-5)	3.83	8.17	0.25
F	(2-6)	13.17	9.50	0.69
G	(3-4)	0	10.00	5.44
H	(3-6)	13.17	4.00	0.11
I	(4-6)	0	7.67	1.00
J	(4-7)	22.83	6.17	0.25
K	(5-6)	3.83	10.67	1.00
L	(5-7)	12.5	6.00	0.44
M	(6-7)	0	4.00	0.11

The results represented in Table 2 shows that the critical path is A-D-G-I-M. This means, that the completion of activities B, C, E, F, H, J, K and L can be delayed up to their floating time and not affect the duration of the project. Since all activities through the path must be completed sequentially without overlapping, the project duration is calculated as the sum of the times required critical path to be completed. The simulations show that the probability distribution of project duration has mean μ=32.83 time units and standard deviation
σ^2=2.63 time units.

The confident coefficient z is calculated as:

$$z = \frac{37 - 32.83}{2.63} = 1.58$$

Thus, the probability that project will be completed in 37-time unit is calculated as:

$$P(T \leq \mu) = P(z \leq 1.58) = 0.94295$$

Project activities duration have uncertainties that have to be considered in order to evaluate project completion probability The code for Monte Carlo simulations is developed in program language C++. Random activity durations for the simulations were generated through pseudo random number generator on the range from optimistic to pessimistic time. The number of Monte Carlo iteration defined in the program is 10000. After analysis of the obtained data, one critical path and two subcritical paths are identified. Results from the simulations are represented in Table 3.

Table 3 Results from Monte Carlo Simulation

	Critical Path	Subcritical Path	
	1-2-3-4-6-7	1-2-3-6-7	1-2-5-6-7
Number of occurrence	6941	573	2486
Occurrence (%)	69.40%	5.73%	24.86%
Mean path duration	33.43	28.72	29.43
Standard deviation	4.45	1.31	2.19

The confident coefficient z for the critical path is calculated as:

$$z = \frac{37 - 33.43}{4.45} = 0.802$$

Thus, the probability that project will be completed in 37-time unit is calculated as:

$$P(T \leq \mu) = P(z \leq 0.802) = 0.77884$$

Conclusion

In this paper, a comparison of PERT and Monte Carlo was represented. From the results represented above can be concluded that Monte Carlo is giving a better identification of the risk. The output of PERT simulation is only one identified critical path, while Monte Carlo identifies not only the critical path, but two subcritical paths. The subcritical paths influence the project completion expected time which lead probability of ending the project on schedule to be decreased. Moreover, Monte Carlo simulations offers a choice of various probability distributions like triangle, normal, gamma etc.

The project completion time calculated by PERT was found to be 32.83 time units, while with Monte Carlo it was found that the completion time is 33.43 time units. The difference between these two approaches is 1.74%.

References

[1] Malcom, D., Roseboom, J., Clark, C., "Application of a Technique for Research and Development Program Evaluation", *Operational Research*, 7, 646-669, 1959.
[2] Tysiak, W. Risk Management in Projects: The Monte Carlo Approach versus PERT. *The 6th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications*, 2011, Czech Republic.
[3] Milian, Z., Monte Carlo Simulation with Exact Analysis for Stochastic PERT Networks, *The 25th Symposium on Automation and Robotics in Construction*, 2008.
[4] Metropolis, N., The Beginning of the Monte Carlo Method, *Los Alamos Science Special Issue*, 1987.
[5] Taha, H. A., Operation Research: An Introduction, 10th Edition, Pearson, 2017.