SIMULATION OF PERT NETWORK AND IT'S VALIDATION

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Abstract
The Pert Technique is a statistical way of representing project milestones as a network diagram. It predicts project completion times putting into consideration, the risk of uncertainty. It allows the project manager who is often responsible for scheduling, and coordinating a series of complex tasks and activities, the ability to monitor the progress of a project. Prior to the commencement of any project, it is important that the project team have an idea of how long it would take to execute the project. This is essential because it makes sure that the project manager knows exactly how long it would take to get the project completed and so can factor that in when deciding on a budget for the project. The objective of this study is to calculate the critical path time for PERT (Program Evaluation and Review Technique) networks. An attempt was made to construct the network in ARENA Simulation Software and the model obtained was compared by manually solving it and results obtained from other software packages like STORM, LINGO.
Keywords: *Simulation modeling, ARENA Simulation Software, PERT, LINGO, STORM, Stochastic model, Project Scheduling.*

Introduction

PERT - Program Evaluation and Review Technique

Program Evaluation and Review Techniques is commonly abbreviated to PERT [2]. PERT is a method of analyzing the tasks involved in completing a given project, especially the time needed to complete each task, and to identify the minimum time needed to complete the total project. It incorporates uncertainty by making it possible to schedule a project while not knowing precisely the details and durations of all the activities. It is more of an event-oriented technique rather than start- and completion-oriented, and is used more in projects where time is the major factor rather than cost.

PERT and CPM are complementary tools, because CPM employs one time estimate and one cost estimate for each activity, so they are classified as a deterministic model and PERT may utilize three time estimates (optimistic, expected, and pessimistic) and no costs for each activity and thereby fall under probabilistic models. Three time values are estimated in PERT for time of conducting each activity. Then average and variance of each activity time are calculated using beta distribution function. The mean and standard deviation for activity time can be calculated using the following formulas:

$\mu =$ ————

$\sigma =$ ——— where, to = optimistic time, tm= most probable time, tp = pessimistic time

Simulation

Simulation is the imitation of the operation of a real-world process or system. The act of simulating something first requires that a model be developed; this model represents the key characteristics, behaviors and functions of the selected physical or abstract system or process.

The model represents the system itself, whereas the simulation represents the operation of the system over time. Simulation is a very useful tool to study systems and take necessary actions without disrupting the real world. Informational, organizational and environmental changes can be simulated and the effect of these alternatives on the model's behavior can be observed.

Simulation Models can be classified

- Static or Dynamic
- Deterministic or Stochastic
- Discrete or continuous

The areas of application of simulation include: Manufacturing, public health, transportation system, computer system performance.

Arena Simulation Software

ARENA Simulation Software is a discrete event simulation and automation software developed by system modeling and acquired by Rockwell automation in 2000.It is designed for analysing the impact of changes involving significant and complex redesign associated with supply chain, manufacturing, processes, logistics, distribution, warehousing and service Systems. ARENA Simulation Software provides the maximum flexibility and breadth of application coverage to the model and any desired level of detail and complexity. In ARENA Simulation Software, the user builds an experiment model by placing modules (boxes of different shapes) that represent processes or logic. Connector lines are used to join these modules together and to specify the flow of entities. While modules have specific actions relative to entities, flow, and timing, the precise representation of each module and entity relative to real-life objects is subject. to the modeler. Statistical data, such as cycle time and WIP (work in process) levels, can be recorded and made output as reports.

Simulation Using Arena Simulation Software: Pert

The network shown in *figure (1)* is simulated using ARENA Simulation Software. [2]

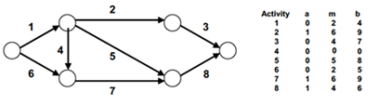


Figure 1 Network Diagram of PERT

The assumptions made for the PERT model are as follows:

1. Arrival of entities follows random exponential distribution.
2. The activities are represented by delay process modules and the type of distribution is triangular for the three times (to, tp, tm).

Method 1

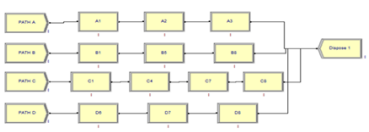


Figure 2 ARENA Simulation Software

This method, as shown in the *figure (2)* is used simulate the PERT network where individual paths are identified. The advantage of this method is that in addition to find the process time we are also able to find the critical path. The dialog box for the PROCESS module is shown in *figure (3).*

The individual paths are: 1-2-3, 1-5-8, 1-4-7-8, 6-7-8. The simulation is run for 10,000 minutes.

Result

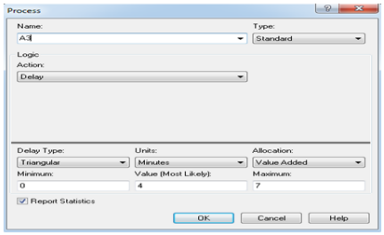


Figure 3: Dialogue box for Process module

Replication ended at time: 10000.0 Minutes

Base Time Units: Minutes

Tally Variables

Identifier Average Half Width Minimum Maximum

Observations

Entity 10026	1.VATime	10.988	.04489	3.3705	18.459
Entity 10026	1.NVATime	.00000	.00000	.00000	.00000
Entity 10026	1.WaitTime	.00000	.00000	.00000	.00000
Entity 10026	1.TranTime	.00000	.00000	.00000	.00000
Entity 10026	1.OtherTime	.00000	.00000	.00000	.00000
Entity 10026	1.TotalTime	10.988	.04489	3.3705	18.459
Entity 9821	2.VATime	9.9901	.04044	2.7814	16.007
Entity 9821	2.NVATime	.00000	.00000	.00000	.00000
Entity 9821	2.WaitTime	.00000	.00000	.00000	.00000
Entity 9821	2.TranTime	.00000	.00000	.00000	.00000
Entity 9821	2.OtherTime	.00000	.00000	.00000	.00000
Entity 9821	2.TotalTime	9.9901	.04044	2.7814	16.007
Entity 9818	3.VATime	11.017	.04848	3.5440	17.423
Entity 9818	3.NVATime	.00000	.00000	.00000	.00000
Entity 9818	3.WaitTime	.00000	.00000	.00000	.00000
Entity 9818	3.TranTime	.00000	.00000	.00000	.00000
Entity 9818	3.OtherTime	.00000	.00000	.00000	.00000
Entity 9818	3.TotalTime	11.017	.04848	3.5440	17.423

Entity 4.VATime 10032	11.336	.04820	3.8880	18.740
Entity 4.NVATime 10032	.00000	.00000	.00000	.00000
Entity 4.WaitTime 10032	.00000	.00000	.00000	.00000
Entity 4.TranTime 10032	.00000	.00000	.00000	.00000
Entity 4.OtherTime 10032	.00000	.00000	.00000	.00000
Entity 4.TotalTime 10032	11.336	.04820	3.8880	18.740

From the SIMAN summary, we can identify the highest time in entity 4 of 11.336 minutes. Therefore the critical path is 6-7-8 and the critical time is 11.336.

Method 2 The simulation model for method 2 is shown in *figure (4).*

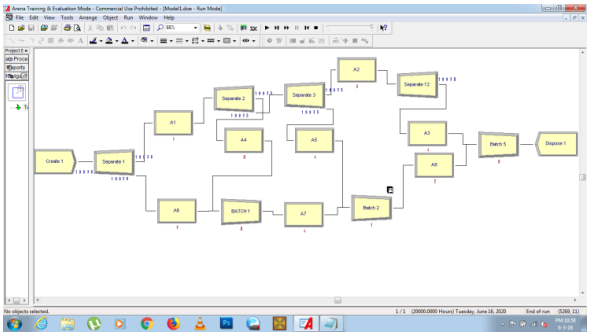


Figure 4 Network Diagram of PERT

In this method, as seen in *figure (4)* SEPARATE and BATCH modules are used to design the network. The separate template module is used to either copy an incoming entity into multiple entities or to split a previously batched entity. The batch module template is intended as the grouping mechanism within the simulation model. The entities arriving

at the batch module are placed in a queue until the required number of entities has been accumulated. The dialogue boxes for separate and batch modules are shown in *figure (5).*

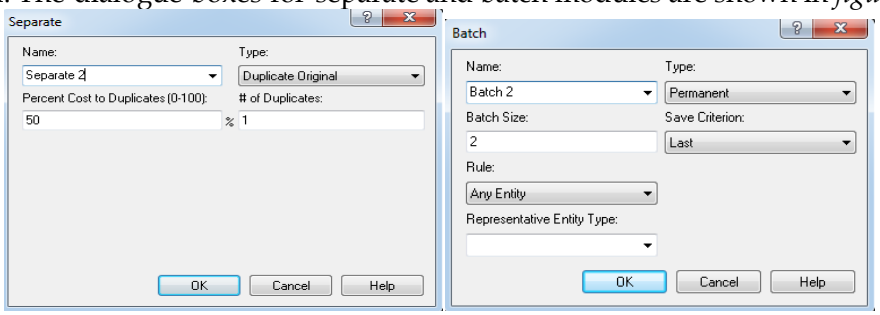


Figure 5 Dialogue Boxes for Separate and Batch Modules

The above simulation is run for 10,000 minutes and the SIMAN summary is obtained.

Result

Replication ended at time: 10000.0 Minutes

Base Time Units: Minutes

Tally Variables

Identifier Observations	Average	Half Width	Minimum	Maximum
Entity 1.VATime	26.567	(Insuf)	17.001	36.241
100				
Entity 1.NVATime	.00000	(Insuf)	.00000	.00000
100				
Entity 1.WaitTime	6.3965	(Insuf)	1.2585	16.610
100				
Entity 1.TranTime	.00000	(Insuf)	.00000	.00000
100				
Entity 1.OtherTime	.00000	(Insuf)	.00000	.00000
100				
Entity 1.TotalTime	12.875	(Insuf)	9.2072	15.854
100				
Batch 2.Queue.WaitingTime	1.3703	(Insuf)	.00000	9.8075
200				
Batch 5.Queue.WaitingTime	1.2486	(Insuf)	.00000	7.9252
200				
BATCH 1.Queue.WaitingTime	.57923	(Insuf)	.00000	4.5486
200				

Discrete-Change Variables

Identifier Value	Average	Half Width	Minimum	Maximum	Final
Entity 1.WIP	.61659	(Corr)	.00000	7.0000	
2.0000 Batch					
2.Queue.NumberInQueue	.02741	(Insuf)	.00000	2.0000	
.00000 Batch					
5.Queue.NumberInQueue	.02497	(Insuf)	.00000	2.0000	
.00000 BATCH					
1.Queue.NumberInQueue	.01158	(Insuf)	.00000	2.0000	
.00000					
The critical path's (6-7-8) time is 12.875.					

Validation

The results obtained from the simulations are compared with results obtained manually, from LINGO and STORM.

Lingo Model

The Program for the LINGO Model is as below:

```
MODEL: SETS:
NODES/1.6/:TIME;
ARC
(NODES,NODES)/
1,2 1,3 2,3 2,5 3,5 2,4 4,6
5,6/:DUR; ENDSETS
MIN=TIME (6)-TIME (1);
@FOR(ARC(I,J):TIME(J)>TIME(I)+DUR(I,J)); DATA:
DUR=1.33,2.1667,0,4.667,5.667,5.667,3.833,
3.83; ENDDATA
END
```

Result

Global optimal solution found.

Objective value: 11.66670

Infeasibilities: 0.000000

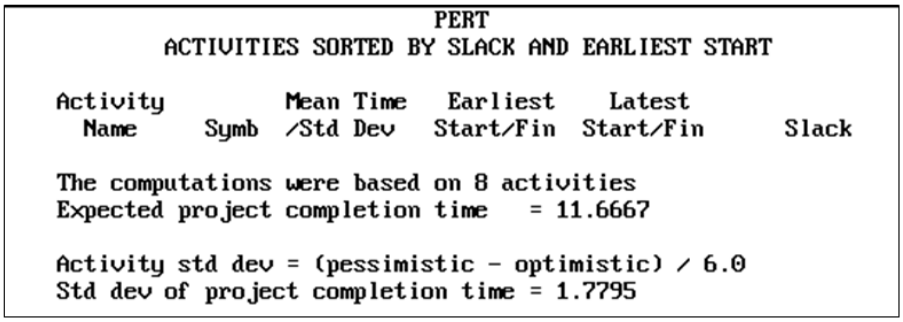
Total solver iterations: 2

Elapsed runtime seconds: 0.06

Model Class: LP

Storm Results

The PERT model is verified in STORM as shown in the *figure (6)*



PERT
ACTIVITIES SORTED BY SLACK AND EARLIEST START

Activity Name	Symb	Mean Time /Std Dev	Earliest Start/Fin	Latest Start/Fin	Slack

The computations were based on 8 activities
Expected project completion time = 11.6667

Activity std dev = (pessimistic - optimistic) / 6.0
Std dev of project completion time = 1.7795

Figure 6 Results Obtained in STORM

Result Comparisons

Results obtained from Simulation, Storm, Lingo and Manual calculations for the Pert Model is tabulated below:

Arena simulation Software : method 1	Arena Simulation software :method 2	Storm	Lingo	Manual
12.875	11.336	11.6667	11.6667	11.6667

Conclusion

Using ARENA Simulation Software PERT models were simulated to calculate the completion of project time. The advantage of simulation is that model can be made for any desired distribution. It is observed that with the increase in the replication length of the simulation, a more accurate result is obtained. These models were also formulated manually and using the software's: STORM, LINGO. The results of these models are found to be comparable, considering that the model was built on Random numbers.

References

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