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Comparative Study on Pert and Simulation Modeling

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ABSTRACT: PERT is one of the widely used management techniques for analyzing commercial and industrial projects from a managerial point of view. It analyses processes in the form of networks and gives an estimate of the overall process completion time. It also identifies the processes that cause the greatest impact to the overall process. These processes are called critical activities and the path they follow is called the critical path. In real time systems the uncertainties associated with the processes are not known before hand and as a consequence meeting the scheduled delivery date becomes difficult. This is because the process time of a critical path is crucial for the completion of the process and if the uncertainties associated with the critical process is not known in advance then the probability of not meeting the delivery date increases. In addition to this experimenting with the actual system is not cost effective. A solution to all the problems associated with analysing the actual system is to simulate the PERT network.

KEYWORDS: PERT, SIMULATION

I. LITERATURE REVIEW

Planned and unplanned maintenance activities must be carried out to retain a system in its operating condition or to restore a failed system to its operating condition. Failure during actual operation is very dangerous and disastrous; hence it is extremely important to avoid failure. (Pham, 1995).

Maintenance is classified into two categories: corrective and preventive. Corrective Maintenance (CM) is the category of maintenance that is employed when a system in an operating condition sustains failures. It is also referred to as repair. Preventive maintenance (PM) is another category of maintenance wherein various activities are carried out to prevent incipient failure from occurring in an operating system.

The following are the different maintenance categories classified based on the degree to which the operating condition of a system is restored by maintenance activities.

a) Perfect repair or perfect maintenance: In this category of maintenance, actions are carried out to restore the systems operating condition to as good as new. A system that has undergone a perfect repair will have the same life distribution and failure rate function as a new one.

b) Minimal repair or minimal maintenance: The action taken in this category of maintenance restores a system to the failure rate it had when it failed. A system that has undergone minimal repair is often referred to be as bad as old.

c) Imperfect repair or imperfect maintenance: It is a category of maintenance wherein the system is not made as good as new but made younger. The state of a system that has undergone an imperfect repair is between old and new. This category of maintenance includes both minimal repair as well as perfect repair.

d) Worse repair or maintenance: It is a category of maintenance wherein the actions taken increases the systems failure rate, however the system does not breakdown. The state of the system upon worse repair becomes worse than that just prior to the repair.

e) Worst repair or maintenance: A category of maintenance which makes the system to fail or breakdown

Some possible causes for imperfect, worse or worst maintenance is (Brown and Proschan, 1983):

- Repairing the wrong part
- Partial repair of the faulty part
- Damaging the parts adjacent to the parts that are repaired

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- Incorrect assessment of the units condition
- Performing maintenance at off schedule

Several other reasons causing worse or worst maintenance (Nakagawa and Yasui, 1987):

- Failing to detect the hidden faults
- Human errors
- Replacement with faulty parts

Earlier studies on preventive maintenance assumed that (1) the system after corrective or preventive maintenance is as good as new (perfect maintenance) or as bad as old (minimal maintenance), and (2) the repair or maintenance times are both assumed to be negligible.

PERT is significantly used in project scheduling, planning and coordinating various interconnected activities. It gives a time estimate for each task and helps to identify critical activities that must be completed to ensure project completion within the estimated time. The project completion time is estimated based on the average completion time of the critical tasks. PERT calculates the critical path as a sequence of activities for which sum of the expected completion times is at a maximum. The PERT method calculates the critical path based on the mean of the activity times thereby reducing the stochastic model to a deterministic model. As a result a single critical path would be generated, but in reality there may be several possible critical paths realized. The accuracy of the project completion time estimated for large networks using the traditional PERT method is very low because the probability of a non-critical path becoming critical is very low. For large networks, computing the critical path lengths from origin to all other nodes is feasible since the PERT network is acyclic. However computation becomes infeasible if the arc lengths are random variables.

Simulation was introduced as a method for analysing project networks by Van Slyke in 1963. There are two main areas of application regarding analysis of project network models using simulation (5). The first area of application is critical path analysis and the second one is considering the resource constraints while simulating. Traditionally, simulation was applied to project network models to generate activity times and criticality indices and/or resource requirement profiles for the purpose of planning and/or controlling the project (5). Application of MC simulation to PERT was demonstrated by Van Slyke to study the accurate estimates of the true project length, flexibility in selecting any distribution for activity times, and the ability to calculate "criticality indexes" .GERT was introduced by Pritzker as a technique for network modeling and simulation. While PERT incorporates only one aspect of uncertainty namely activity duration, GERT includes a second aspect of uncertainty which is the stochastic nature of the network structure (5, 9, 10, and 13). The traditional approach of analyzing PERT/CPM using single-valued estimation resulted in deterministic time estimates and a crude (0, 1) probability estimate of activity criticality (5). An interesting, but often overlooked, point regarding the simulation of PERT/CPM-type networks is that these simulations are not, in general, conducted in a dynamic mode (7). Project-network precedence constraints problems that occur when simulating PERT/CPM network are resolved by generating sample duration for each activity, and then processing the data in a sequence (5).

Computer Assisted PERT Simulation (CAPERTSIM) was developed by Ameen for project management studies to evaluate decision making under uncertainty and cost-time relationships and trade-offs. Badiru developed another simulation program for project management, called STARC. STARC allows the user to calculate the probability of completing the project by a specified deadline. It also allows the user to enter a "duration risk coverage factor". The duration risk coverage factor is a percentage over which the time range of activities are extended. It generates activity times above the pessimistic time and below the optimistic time

II. METHODOLOGY

The methodology of the simulation based PERT/CPM consists of two phase's. In the first phase the actual manufacturing process is mapped in the form of a PERT network and in the second phase the repair operation is modeled. Simulation is used to model machine failure times and variation in repair times to study the effect of variation on the manufacturing lead time. The time to initiate a repair operation is not changed as the purpose of the study is subjected to repair time. Since the primary focus of the paper is to study the effect of repair time variation on the manufacturing lead time the repair operation is studied extensively by sub-dividing the repair process into sub-

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processes The sub-processes represents the various tasks required to complete the repair process. Variations are added to these sub-processes and simulated to determine the manufacturing lead time which is actually the lead time of the critical path. The entire process is simulated by varying the repair time to determine the new manufacturing lead time and the process path which generates this lead time. This is to check if a new path has become critical due to the variations in the repair operation. The specific repair operation task responsible for the change in the lead time is identified and managed to improve the probability of meeting the delivery date.

Phase 1: Mapping the PERT Network
In this phase the actual manufacturing process is represented as a PERT network diagram. Each node corresponds to a process which has a specific duration. The type of failure occurring is assumed to be machine breakdown and the failure time is assumed to follow an exponential distribution. The model is programmed in a way such that the machine fails after a specific duration and when it fails it initiates a repair operation and remains non-operational until the repair operation is completed. The process lead time which is the sum of machine operation time and the repair duration is calculated from simulation. The metric that is measured in this phase is process lead time which is referred to as Mean Lead Time (MLT).

Mean Lead Time = Mean Time of Operation + Mean Time between Repair

MLT = $\sum_{i=1}^{n}(MTOO_i + MTBR_i)$, I represents the processes.

Phase 2: Modelling Repair Operation
In this phase the tasks involved in repairing failed equipment is modelled. Every task is modelled with specific variation times. Simulation is used to identify the sub-task that increases the repair lead time. The metric measured in this phase is Mean Time between Repair (MTBR). MTBR can be expressed as combination of time spent in identifying the type of repair and allocating tools and resources to perform the repair.

Mean Time between Repair = Mean Time to Identify + Mean Time to Allocate

$$\text{MTBR} = \sum_{i=1}^{n}(MTTI_i + MTTA_i)$$

Mean Time to Identify = Mean Time to Identify the Type of Failure + Mean Time To Identify the Type of Failure

$$MTTI = MTTI_t + MTTI_s$$

Mean Time to Allocate = Mean Time to Allocate Tools + Mean Time to Allocate Resources

$$MTTA = MTTA_t + MTTA_r$$

III.CONCLUSION

Simulation is used to model the actual process with uncertainties and study the behaviour of the system to these uncertainties. This approach has an advantage of being simple and more cost effective. Analysing networks using simulation not only predicts an unbiased estimate of the mean and variance of the processes but also gives the probability of a non-critical path becoming critical. A similar approach is used in this paper wherein the actual manufacturing system is modelled as a PERT network using simulation. Uncertainties are incorporated into the

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model and tested for various scenarios to determine the process completion time, mean completion time of individual processes and also the probability of a non-critical process becoming critical.

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8. ^ Jump up to: [a] [b] J. Banks, J. Carson, B. Nelson, D. Nicol (2001). *Discrete-Event System Simulation*. Prentice Hall. p. 3. ISBN 0-13-088702-1.
9. Jump up ^ In the words of the Simulation article in Encyclopedia of Computer Science, "designing a model of a real or imagined system and conducting experiments with that model".
10. Sokolowski, J.A., Banks, C.M. (2009). *Principles of Modeling and Simulation*. Hoboken, NJ: Wiley. p. 6. ISBN 978-0-470-28943-3.
11. Jump up ^ For example in computer graphics SIGGRAPH 2007 | For Attendees | Papers Doc:Tutorials/Physics/BSoD - BlenderWiki.
12. Jump up to: [a] [b] Thales defines synthetic environment as "the counterpart to simulated models of sensors, platforms and other active objects" for "the simulation of the external factors that affect them"[1] while other vendors use the term for more visual, virtual reality-style simulators [2].
13. Jump up ^ For a popular research project in the field of biochemistry where "computer simulation is particularly well suited to address these questions"Folding@home - Main, see Folding@Home.
14. Jump up ^ For an academic take on a training simulator, see e.g. Towards Building an Interactive, Scenario-based Training Simulator, for medical application Medical Simulation Training Benefits as presented by a simulator vendor and for military practice A civilian's guide to US defense and security assistance to Latin America and the Caribbean published by Center for International Policy.
15. Jump up ^ Classification used by the Defense Modeling and Simulation Office.