Middle-East Journal of Scientific Research 18 (12): 1695-1699, 2013
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2013.18.12.1001

Optimizing Maintenance and Repair Policies by Reliability Modelling

[1]*G. Tamizharasi and* [2]*S. Kathiresan,*

[1]Bharath University, Chennai, India
[2]Karpaga Vinayaga College of Engineering and Technology, India

Abstract: The objective of this paper is to present a reliability model which can optimize the maintenance and repair policies. The component failure-rate uncertainty is taken under consideration and a reliability model is created by simulation approach. Most of the published results in this area are based on analytical modelling using various probability distributions and then trying to find an exact expression for system reliability, which may be very difficult to obtain. Also, if there are any changes in the management policies regarding the maintenance and repair, rebuilding and modifying the analytical model is too complex in nature. Incorporating the multiple objectives, identifying the bottlenecks, producing the graphical user interface and sensitivity analysis are mostly time consuming tasks in an analytical model. Hence it is proposed to build a simulation model, which can effectively incorporate the above said requirements. The proposed reliability model is built by using Extend-A Simulation Tool, by which the observer can easily understand the system. The model contains components (called “blocks”), usually with connections between the blocks. After the creation of the model, the modifications can be done by adding block, moving connections and changing block data. The model developed has been applied to maintenance and repairs of bearings of a large milling machine. This model can be scaled to any number of machines, bearings and repairpersons with stochastic repair, delay times. A full-featured authoring environment is provided for simplifying the model interaction and enhancing communication. The “step wise refinement” enables to achieve good approximations of very complex problems surprising quickly and because of the refinements the model becomes more and more accurate. The stochastic nature of the best solutions for the single objective optimization modeling of the system design is sampled extensively and the robustness of the developed optimization approach is demonstrated with cost effectiveness.

Key words: Simulation · Reliability · Stochastic · Maintenance

INTRODUCTION

The monitoring information (failure time or degradation level) is of great importance for the maintenance decision-making. In case of stochastic dependences between components (e.g. the state of each component is correlated to the state of the others [1, 2], it can be shown that the maintenance policies can be significantly improved if the monitoring information is taken into account for the maintenance decision making [3, 4]. The model presented in [4] allows optimizing a preventive replacement time only considering partial monitoring. Changes in the type of distribution of an activity, constraints and logical relationship among activities reduce the effectiveness of mathematical model. More over if changes in the management policies regarding the maintenance and repair policies are subjected to frequent changes it is more time consuming to see the effect of changes i.e sensitivity analysis by the analytical model. Hence it is proposed to build a simulation model which will incorporate all the above said changes to achieve an optimized level in maintenance and repair policies. A numerical example demonstrates the usability of our approach.

Simulation: Simulation is the manipulation of a model in such a way that it operates on time or space to compress it, thus enabling one to perceive the interactions that would not otherwise be apparent because of their separation in time or space. Simulation generally refers to

Corresponding Author: G. Tamizharasi, Bharath University, Chennai, India.

a computerized version of the model, which is run over time to study the implications of the defined interactions. Simulations are generally iterative in there development. One develops a model, simulates it, learns from the simulation, revises the model and continues the iterations until an adequate level of understanding is developed.

System Simulation: A system is understood to be an entity, which maintains its existence through the interaction of its parts. A model is a simplified representation of the actual system intended to promote understanding. Whether a model is a good model or not depends on the extent to which it promotes understanding. Since all models are simplifications of reality there is always a trade-off as to what level of detail is included in the model. If too little detail is included in the model one runs the risk of missing relevant interactions and the resultant model does not promote understanding. If too much detail is included in the model the model may become overly complicated and actually preclude the development of understanding. System can be categorized as discrete of continuous. A discrete system is one in which the state variable (s) change only at a discrete set of points in time. The production line is an example of a discrete system, since the state variable, the number of jobs in the line, changes only when a job arrives or when the processing is completed. A continuous system is one in which the state variable(s) change continuously over time. An example is the head of water behind a dam. During and for some time after a rainstorm, water flows into the lake behind the dam. Water is drawn from the dam for flood control and to make electricity. Evaporation also decreases the water level.

Discrete event simulation is one way of building up models to observe the time based (or dynamic) behavior of a system. There are formal methods for building simulation models and ensuring that they are credible. During the experimental phase the models are executed (run over time) in order to generate results. The results can then be used to provide insight into a system and a basis to make decisions on.

Extend V6 - Simulation Tool: To get the animated flow of resources it is decided to use Extend to create models from building blocks, explore the processes involved and see how they relate. Then change assumptions to arrive at an optimum solution. Extend and our imagination are all we need to create professional models that meet all our business, industrial and academic needs. Simulation provides a method for checking our understanding of the world around us and helps us produce better results faster. A simulation program like Extend is an important tool that we can use to predict the course and results of certain actions,understand why observed events occur, identify problem areas before implementation, explore the effects of modifications, confirm that all variables are known, evaluate ideas and identify inefficiencies,gain insight and stimulate creative thinking,communicate the integrity and feasibility of our plans.

Modeling And Simulation: A model is a logical description of how a system performs. Simulation involves designing a model of a system and carrying out experiments on it as it progresses through time. Modeling and Simulation is a discipline for developing a level of understanding of the interaction of the parts of a system and of the system as a whole. The level of understanding, which may be developed via this discipline, is seldom achievable via any other. discipline.

Simulation with Extend means that instead of interacting with a real system, we create a model which corresponds to it in certain aspects.We can use a model to describe how a real-world activity will perform. Models also enable us to test hypotheses at a fraction of the cost of actually undertaking the activities that the models simulate. For example, if we are a hardware designer, we can use Extend to simulate the performance of a proposed system before building it.

One of the principal benefits of a model is that we can begin with a simple approximation of a process and gradually refine the model as our understanding of the process improves. This "stepwise refinement" enables us to achieve good approximations of very complex problems surprisingly quickly. As we add refinements, our model becomes more and more accurate. An Extend model is a document that contains components (called "blocks"), usually with connections between the blocks. Each block contains procedural information as well as data that we enter. After we create a model, we can modify it by adding blocks, moving connections and changing block data.

Discrete-Event System Simulation: The modeling of systems in which the state variables changes only at a discrete set of points in time. In the case of simulation modes, which employ numerical methods, models are “run” rather than solved; that is, an artificial history of the system is generated based on the model assumptions and observations are collected to be analyzed and to estimate the true system performance measures.

An Extend model is a document that contains components (called "blocks"), usually with connections between the blocks. Each block contains procedural information as well as data that we enter. After we create a model, we can modify it by adding blocks, moving connections and changing block data. Animations of resource flow make the observer of the model to easily understand the flow and it also provides means for identifying bottlenecks. From the simulated model utilization percentages and stock out days can be effectively controlled.

Using simulation an analyst can introduce the constants and variables related to the problem, set up the possible courses of action and establish criteria, which acts as measure of effectiveness. It is desirable tool for solving business problem when a mathematical model is too complex to solve and/or beyond the capacity of the available personnel [5].

A Numerical Example: In this section we want to demonstrate the applicability of the proposed approach by a numerical example. A large milling machine has three different bearings that fail in service. The cumulative distribution function of the life of each bearing is identical as shown in Table 3.1. When a bearing fails, the mill stops, a repair person is called and a new bearing is installed [6-10].

The delay time of the repairperson's arriving at the milling machine is also a random variable, with the distribution given in Table 3.2. Down time for the mill is estimated as

Table 3.1: Bearing Life Distribution

Bearing Life (Hours)	Probability	Cumulative Probability	Random Digit Assignment
1000	0.1	0.1	10-Jan
1100	0.13	0.23	23-Nov
1200	0.25	0.48	24-48
1300	0.13	0.61	49-61
1400	0.09	0.7	62-70
1500	0.12	0.82	71-82
1600	0.02	0.84	83-84
1700	0.06	0.9	85-90
1800	0.05	0.95	91-95
1900	0.05	1	96-00

Table 3.2: Delay-Time Distribution

Delay time (Minutes)	Probability	Cumulative Probability	Random Digit Assignment
5	0.6	0.6	6-Jan
10	0.3	0.9	9-Jul
15	1	1	0

Rs 5 per minute. The direct on site cost of the repairperson is Rs12 per hour. It takes 20 minutes to change one bearing, 30 minutes to change two bearing and 40 minutes to change three bearings. The bearings cost Rs16 each. A proposal has been made to replace all three bearings whenever a bearing fails. Management needs an evaluation for this proposal.

Table 3.4 is an analytical simulation table for the stated problem. Notice that as long as possible, the same life time appear for all the three bearings. It is assumed that the bearings are in order on a shelf and they are taken sequentially and placed on the mill. The random digits that lead to the lives of the additional bearings are

Table 3.3: Bearing Replacement Using Current Method

	Bearing 1					Bearing 2					Bearing 3				
	R*D	Life (Hrs)	Accu- Mulated Life (Hours)	RD	Delay (Min)	RD	Accu- Mulated Life (Hrs)	Life (Hrs)	RD	Delay (Min)	RD	Life (Hrs)	Accu-Mulated Life (Hours)	RD	Delay (Min)
1	67	1400	1400	2	5	70	1500	1500	0	15	76	1500		0	1
2	8	1000	2400	3	5	43	1200	2700	7	10	65	1400	1500	2	5
3	49	1300	3700	1	5	86	1700	4400	3	5	61	1400	2900	7	10
4	84	1600	5300	7	10	93	1800	6200	1	5	96	1900	4300	1	5
5	44	1200	6500	8	10	81	1600	7800	2	5	65	1400	6200	3	5
6	30	1200	7700	1	5	44	1200	9000	8	10	56	1300	7600	3	5
7	10	1000	8700	2	5	19	1100	10100	1	5	11	1100	8900	6	5
8	63	1400	10100	8	10	51	1300	11400	1	5	86	1700	10000	3	5
9	2	1000	11100	3	5	45	1300	12700	7	10	57	1300	11700	1	5
10	2	1000	12100	8	10	12	1100	13800	8	5	49	1300	13000	4	5
11	77	1500	13600	7	10	48	1300	15100	0	15	36	1200	14300	8	10
12	59	1300	14900	5	5	9	1000	16100	8	10	44	1200	15500	2	5
13	23	1100	16000	5	5	44	1200	17300	1	5	94	1800	16700	1	5
14	53	1300	17300	9	10	46	1200	18500	2	5	78	1500	18500	7	10
15	85	1700	19000	6	5	40	1200	19700	8	10			20000		
16	75	1500	20500	4	5	52	1300	21000	5	5					
	Total Delay				110	Total Delay				125		Total Delay			95

*Random digits

Table 3.4: Bearing Replacement Using Analytical Simulation

	Bearing 1 Life (Hours)	Bearing 2 Life (Hours)	Bearing 3 Life (Hours)	First Failure (Hours)	Accumulated Life (Hours)	RD	Delay (Minutes)
1	1400	1500	1500	1400	1400	3	5
2	1000	1200	1400	1000	2400	7	10
3	1300	1700	1400	1300	3700	5	5
4	1600	1800	1900	1600	5300	1	5
5	1200	1600	1400	1200	6500	4	5
6	1200	1200	1300	1200	7700	3	10
7	1000	1100	1100	1000	8700	7	10
8	1400	1300	1700	1300	10000	8	10
9	1000	1300	1300	1000	11000	8	5
10	1000	1100	1300	1000	12000	3	5
11	1500	1300	1200	1200	13200	2	5
12	1300	1000	1200	1000	14200	4	5
13	1100	1200	1800	1100	15300	1	5
14	1300	1200	1500	1200	16500	6	5
15	1700	1200	63/1400	1200	17700	2	5
16	1500	1300	21/1100	1100	18800	7	10
17	85/1700	53/1300	23/1100	1100	19900	0	15
18	05/1000	29/1200	51/1300	1000	20900	5	5
	Total Delay						125

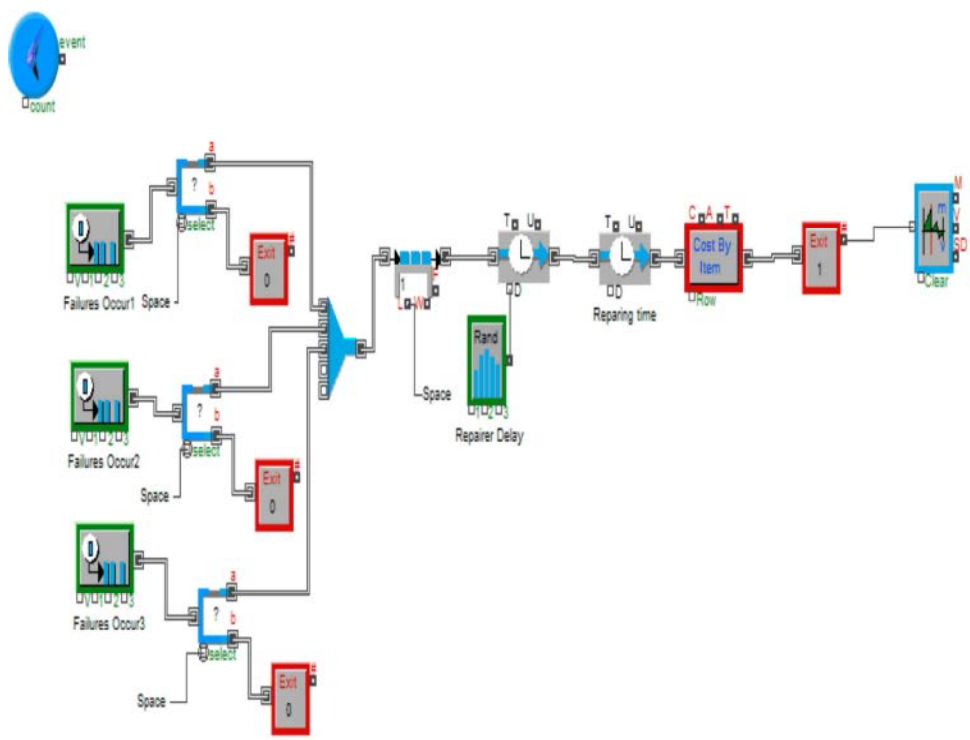

Fig. 4.1: Optimized Reliability Model

shown above the slashed line beginning with the 15th replacement of bearing 3.When the new policy is used, some 18 sets of bearings were required. In the two simulations, repairperson delays were not duplicated but were generated independently. The total cost of new policy is computed as follows:

- Cost of bearings = 54 bearings x Rs16/bearing = Rs 864
- Cost of delay time= 125 x Rs 5/minute = Rs 625
- Cost of down time during repair = 18 sets x 40 minutes/set x Rs 5/minute = Rs 3600

- Cost of repairpersons = 18 sets X 40 minutes/bearing x Rs 12/ 60minute = Rs 144
- Total Cost = Rs 864 + Rs 625 + Rs 3600 + Rs 144 = Rs 5233.

EXTEND – Reliability Simulation Model: Initially by "EARDEAF" analysis the entities, activities, resources, decisions, events, attributes, flows are identified for the above stated problem.

Entity	:	Fault
Activity	:	Arrival of repair person, repair time
Resources	:	Repair person
Decisions	:	(i) To replace the failed bearings only (ii)To replace all the three bearings
Events	:	Bearing failure, Arrival repair person, finish of repairing
Attributes	:	Occurrence of failure, finish time of repair
Flow	:	Discrete Event flow

Then appropriate blocks are selected for model building from EXTEND and after several reviews the optimized model is built with resource flow animations as shown in Figure 4.1. Simultanious replacement of three bearings gives the result as total cost of Rs4921.90 for ten simulation runs of 20000 hours with 17 replacements which is the optimal cost when compared with the analytical simulation of discrete replacements. The simulated model for control will be significant for prediction of the course and results of certain actions, to understand why observed events occur, identify problem areas before implementation,explore the effects of modifications,confirm that all variables are known,evaluate ideas and identify inefficiencies,gain insight and stimulate creative thinking,communicate the integrity and feasibility of your plans,and to produce ustomizable reports for presentation and in-depth analysis.

CONCLUSION

In the present paper, it is described how to use the simulation optimization approach for optimizing maintenance and repair policies. Of course the results presented here can be only a starting point for further research with different investigation goals. Future research can go into various directions, i.e. at least into the operations research direction or into the computational direction. With respect to the first variant it seems to be promising to investigate the influence of various model parameters on interesting performance measures. This in general can be done only by empirical work. The consideration of other policies will be interesting. The same will hold if we try for instance to find conditions under which a given policy class dominates other ones.

REFERENCES

1. Cinlar, E., M. Shaked and J. Shanthikumar, 1989. On Lifetimes Inuenced by a Common Environnement. Stochastic Processes and their Applications, 33: 347-359.
2. Bhattacharya, A., 1996. Reliability Evaluation of Systems with Dependent Failures. International Journal of Systems Science, 27: 881-885.
3. Aven, T. and U. Jensen, 1999. Stochastically Models in Reliability, Volume 41 of Applications of Mathematics. Springer.
4. Heinrich, G. and U. Jensen, 1996. Bivariate Lifetime Distributions and Optimal Replacement. Mathematical Methods of Operations Research, 44: 31-47.
5. Jerry banks, 1998. Discrete event system simulation, Prentice Hall India.
6. Sokeng, S.D., D. Lontsi, P.F. Moundipa, H.B. Jatsa, P. Watcho and P. Kamtchouing, 2007. Hypoglycemic Effect of Anacardium occidentale L. Methanol Extract and Fractions on Streptozotocin-induced Diabetic Rats, Global Journal of Pharmacology, 1(1): 01-05.
7. Prajapati Hetal Ritesh, Brahmkshatriya Pathik Subhashchandra, Vaidya Hitesh Bharatbhai and V. Thakkar Dinesh, 2008. Avian Influenza (Bird Flu) in Humans: Recent Scenario, Global Journal of Pharmacology, 2(1): 01-05.
8. Okafor, P.N., K. Anoruo, A.O. Bonire and E.N. Maduagwu, 2008. The Role of Low-Protein and Cassava-Cyanide Intake in the Aetiology of Tropical Pancreatitis, Global Journal of Pharmacology, 2(1): 06-10.
9. Nahed, M.A., Hassanein, Roba M. Talaat and Mohamed R. Hamed, 2008. Roles of Interleukin-1 (Il-1) and Nitric Oxide (No) in the Anti-Inflammatory Dynamics of Acetylsalicylic Acid Against Carrageenan Induced Paw Oedema in Mice, Global Journal of Pharmacology, 2(1): 11-19.
10. Panda, B.B., Kalpesh Gaur, M.L. Kori, L.K. Tyagi, R.K. Nema, C.S. Sharma and A.K. Jain, 2009. Anti-Inflammatory and Analgesic Activity of Jatropha gossypifolia in Experimental Animal Models, Global Journal of Pharmacology, 3(1): 01-05.