Journal of Advances and Scholarly Researches in Allied Education
Vol. 16, Issue No. 6, May-2019, ISSN 2230-7540

Cost Benefit Analysis of a Two Unit Model with Priority to Preventive Maintenance of the Unit over Other Activity Done By the Server

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***Abstract** – In view of some practical situations in mind that idea of priority to one discipline over another discipline plays very important role to enhance the profit of the system, the motive of the present manuscript is to analyze a cold standby system by giving priority to preventive maintenance over repair. Two identical units are taken having two modes- operative and complete failure. There is a single server who visits the system immediately for conducting maintenance and repair. Server conducts preventive maintenance of the unit after a maximum operation time 't'. However, repair of the unit is done at its complete failure. Priority is given to preventive maintenance of one unit over repair of the other unit. The random variables associated with failure time, completion of maximum operation time, preventive maintenance and repair times are statistically independent. The failure time of the unit and the time by which unit undergoes for preventive maintenance and repair times are taken as arbitrary. Graphs are drawn to depict the behavior of MTSF, availability and profit function for particular values of various parameters and costs.*

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INTRODUCTION

After the Second World War numbers of systems or units were found fail during their operation time, before operation time as well as between the operation times. Researchers were found lot of reason for their failure as well as suggested to improve their performance during such situations. In literature, the stochastic behavior of cold standby system has been widely discussed by many researchers including, Osaki and Nakagawa [1971] discussed a two-unit standby redundant system with standby failure. Nakagawa and Osaki [1975] analyzed stochastic behavior of a two-unit priority standby redundant system with repair. Subramanian et al. [1976] explored reliability of a repairable system with standby failure. Gopalan and Nagarwalla [1985] evaluated cost benefit analysis of one server two unit cold standby system with repair and age replacement. Gupta and Goel [1989] studied profit analysis of two-unit priority standby system with administrative delay in repair.

Reliability and availability analysis of a system with standby and common cause failures have been explained by Dhillon [1992]. Lam [1997] studied a maintenance model for two–unit redundant system. Malik [2009] discussed reliability modelling and cost-benefit analysis of a system – A case study. Dhankhar and Malik [2011] studied cost- benefit analysis of system reliability models with server failure during inspection and repair. Bhardwaj and Kaur [2014] analyzed reliability and profit of a redundant system with possible renewal of standby subject to inspection.

Recently, Grewal *et al.* [2017] obtained economic analysis of a system having duplicate cold standby unit with priority to repair of original unit. Rohila and Kumar [2018] analyzed cost benefit of industry having duplicate cold standby unit with different failure rate. Rohila [2019] studied the cost-benefit analysis of a two unit system model with the concept with server facility-FCFS. The present paper is to analyze a cold standby system by giving priority to preventive maintenance over repair. Two identical units are taken having two modes-operative and complete failure. There is a single server who visits the system immediately for conducting maintenance and repair. Server conducts preventive maintenance of the unit after a maximum operation time 't'. However, repair of the unit is done at its complete failure. Priority is given to preventive maintenance of one unit over repair of the other unit. The random variables associated with failure time, completion of maximum operation time, preventive maintenance and repair times are statistically independent. The failure time of the unit and the time by which unit undergoes for preventive maintenance and repair times are taken as arbitrary. Several measures of system effectiveness such as transition probabilities mean sojourn times, mean time to system failure (MTSF), availability, busy period of the server due to maintenance and repair, expected number of maintenances and repairs of the unit and profit function are obtained using semi-Markov process and regenerative point technique. Graphs are drawn to depict the behavior of MTSF, availability and profit function for particular values of various parameters and costs.

NOTATIONS

E_0 : Set of regenerative states.

O/Cs : The unit is operative/cold standby.

α_0 : The rate by which unit undergoes for preventive maintenance.

λ : Constant failure rate of the unit.

f(t)/F(t) : pdf /cdf of preventive maintenance time.

g(t)/G(t) : pdf /cdf of repair time of a failed unit.

P_m/WP_m: The unit is under preventive maintenance/waiting for preventive maintenance.

PM/FUR: The unit is under preventive maintenance/under repair continuously from previous state.

FU_r/Fw_r : The failed unit is under repair/waiting for repair.

m_{ij} : The unconditional mean time taken by the system to transit from any regenerative state S_i when it (time) is counted from epoch of entrance in to that state S_j. Mathematically, it can be written as

$$m_{ij} = \int_0^\infty t\,d[Q_{ij}(t)] = -q_{ij}^{*'}(0) .$$

μ_i : The mean Sojourn time in state S_i which is given by

$$\mu_i = E(t) = \int_0^\infty P(T > t)dt = \sum_j m_{ij}$$

, where T denotes the time to system

failure.

$W_i(t)$: Probability that the server is busy in the state S_i up to time 't' without

making any transition to any other regenerative state or returning to

the same state via one or more regenerative states.

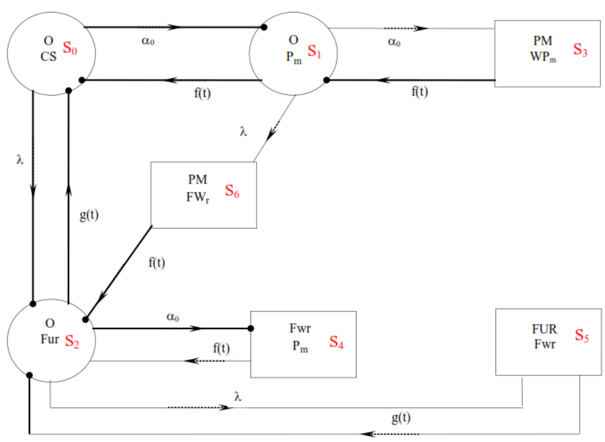
⊗/⊕ : Symbol for Laplace Stieltjes convolution/Laplace convolution.

~/* : Symbol for Laplace Stieltjes transform/ Laplace transform.

′(desh) : Used to represent alternative result.

SYSTEM DESCRIPTION AND ASSUMPTIONS

1. The system has of two identical units which may fail directly from normal mode.
2. Initially one unit is operative and the other is kept as spare in cold standby.
3. There is a single server who visits immediately to the system.
4. The preventive maintenance of the unit is carried out after a maximum operation time.
5. Repair of the unit is done at its failure.
6. The server cannot leave the system while performing jobs.
7. The unit works as a new after repair and preventive maintenance.
8. The switch over is instantaneous and perfect.
9. Priority is given to preventive maintenance over repair. The failure time of the unit and the rate by which unit undergoes for preventive maintenance follow negative exponential distributions.
10. The distributions for preventive maintenance and repair times of the units are taken as arbitrary with different probability density functions.
11. All random variable are statistically independent.



State Transition Diagram Figure 1

Transition Probabilities and Mean Sojourn Times

The differential transition probabilities considerations yield the following expressions for non-zero elements

$$p_{ij} = Q_{ij}(\infty) = \int q_{ij}(t)dt\,;\; p_{01} = \frac{\alpha_0}{\alpha_0+\lambda},\; p_{02} = \frac{\lambda}{\alpha_0+\lambda},\; p_{10} = f^*(\alpha_0+\lambda)$$
$$p_{13} = p_{11.3} = \frac{\alpha_0}{\alpha_0+\lambda}[1-f^*(\alpha_0+\lambda)],\; p_{16} = p_{12.6} = \frac{\lambda}{\alpha_0+\lambda}[1-f^*(\alpha_0+\lambda)]\; p_{20} = g^*(\alpha_0+\lambda),$$
$$p_{25} = p_{22.5} = \frac{\lambda}{\alpha_0+\lambda}[1-g^*(\alpha_0+\lambda)]$$
$$p_{24} = p_{21.4} = \frac{\alpha_0}{\alpha_0+\lambda}[1-g^*(\alpha_0+\lambda)],\; p_{31} = p_{42} = p_{52} = p_{62} = 1 \qquad (1)$$

It can be easily verified that

$$p_{01} + p_{02} = p_{10} + p_{13} + p_{16} = p_{20} + p_{24} + p_{25} = 1 \qquad (2)$$

The mean sojourn time (μ_i) in the regenerative state S_i are defined as the time of stay in that state before transition to any other state. If T denotes the sojourn time in the regenerative state S_i, then

$$\mu_i = E(T) = P_i(T > t)dt \qquad (3)$$

Thus, $\mu_0 = \frac{1}{\alpha_0+\lambda}$, $\mu_1 = \frac{1}{\alpha_0+\lambda}[1-f^*(\alpha_0+\lambda)]$, $\mu_2 = \frac{1}{\alpha_0+\lambda}[1-g^*(\alpha_0+\lambda)]$

$$\mu_1' = \frac{(1-f^*(\lambda+\alpha_0))(1-\alpha_0 f^{*\prime}(0))}{(\lambda+\alpha_0)} \text{ and } \mu_2' = \frac{(1-g^*(\lambda+\alpha_0))(1-(\lambda+\alpha_0)g^{*\prime}(0))}{(\lambda+\alpha_0)}$$

The unconditional mean time taken by the system to transit for any regenerative state S_j when it (time) is counted from the epoch of entrance into the state S_i is mathematically, states as

$$m_{ij} = \int_0^\infty t q_{ij}(t)dt = -q_{ij}^{*\prime}(0) \qquad (4)$$

RELIABILITY AND MEAN TIME TO SYSTEM FAILURE (MTSF)

Let $\phi_i(t)$ be the c.d.f. of first passage time from the regenerative state S_i to a failed state. Regarding the failed state as absorbing state, we have the following recursive relations for $\phi_i(t)$;

$$\phi_0(t) = Q_{01}(t) \otimes \phi_1(t) + Q_{02}(t) \otimes \phi_2(t)$$
$$\phi_1(t) = Q_{10}(t) \otimes \phi_0(t) + Q_{13}(t) + Q_{16}(t)$$
$$\phi_2(t) = Q_{20}(t) \otimes \phi_0(t) + Q_{25}(t) + Q_{24}(t) \qquad (5)$$

Taking Laplace–Stieltjes transform of above relations (5) and solving for $\tilde{\phi}_0(s)$.

We have

$$R^*(s) = \frac{1-\tilde{\phi}_0(s)}{s} \qquad (6)$$

The reliability of the system model can be obtained by taking Laplace inverse transform of (6). The mean time to system failure (MTSF) is given by

$$MTSF = \lim_{s\to 0} \frac{1-\tilde{\phi}_0(s)}{s} = \frac{\mu_0 + \mu_1 p_{01} + \mu_2 p_{02}}{1 - p_{01}p_{10} - p_{02}p_{20}}$$
$$= \frac{(\alpha_0+\lambda) + \alpha_0\{1-f^*(\alpha_0+\lambda)\} + \lambda\{1-g^*(\alpha_0+\lambda)\}}{(\alpha_0+\lambda)^2 - [\alpha_0 f^*(\alpha_0+\lambda) + \lambda g^*(\alpha_0+\lambda)]} \qquad (7)$$

AVAILABILITY ANALYSIS

Let $A_i(t)$ be the probability that the system is in up-state at instant 't' given that the system entered regenerative state S_i at t=0. The recursive relations for $A_i(t)$ are given as

$$A_0(t) = M_0(t) + q_{01}(t) \oplus A_1(t) + q_{02}(t) \oplus A_2(t)$$
$$A_1(t) = M_1(t) + q_{10}(t) \oplus A_0(t) + q_{11.3}(t) \oplus A_1(t) + q_{12.6}(t) \oplus A_2(t)$$
$$A_2(t) = M_2(t) + q_{20}(t) \oplus A_0(t) + q_{22.5}(t) \oplus A_2(t) + q_{24}(t) \oplus A_4(t)$$
$$A_4(t) = q_{42}(t) \oplus A_2(t) \qquad (8)$$

Here, $M_i(t)$ is the probability that the system is up initially in state $S_i \in E$ is up at time t without visiting to any other regenerative state, we have

$$M_0(t) = e^{-(\alpha_0+\lambda)t},\; M_1(t) = e^{-(\alpha_0+\lambda)t}\overline{F(t)} \text{ and } M_2(t) = e^{-(\alpha_0+\lambda)t}\overline{G(t)} \qquad (9)$$

Taking L.T. of above relations (8) and (9) and solving for $A_0^*(s)$, The steady state availability is given by

$$A_0(\infty) = \lim_{s\to 0} sA_0^*(s) = \frac{N}{D}$$

where

$$N = [g^*(\lambda+\alpha_0)(\lambda+\alpha_0 f^*(\lambda+\alpha_0)) + \alpha_0 g^*(\lambda+\alpha_0)(1-f^*(\lambda+\alpha_0)) + \lambda(1-g^*(\lambda+\alpha_0))]/(\lambda+\alpha_0)^2$$
$$D = [\alpha(\lambda+\alpha_0)g^*(\lambda+\alpha_0)(\lambda+\alpha_0 f^*(\lambda+\alpha_0)) + \alpha\alpha_0(\lambda+\alpha_0)g^*(\lambda+\alpha_0)(1-f^*(\lambda+\alpha_0))(1-(\lambda+\alpha_0)g^{*\prime}(0)) + \alpha\lambda(1-g^*(\lambda+\alpha_0)(1-(\lambda+\alpha_0)g^{*\prime}(0)) + \lambda\alpha_0(\lambda+\alpha_0)(1-g^*(\lambda+\alpha_0))/\alpha(\lambda+\alpha_0)^3 \qquad (10)$$

BUSY PERIOD ANALYSIS FOR SERVER DUE TO PREVENTIVE MAINTENANCE

Let $B_i^p(t)$ be the probability that the server is busy in preventive maintenance of the unit at an instant 't' given that system entered state S_i at t=0. The recursive relations for $B_i^p(t)$ are as follows:

$$B_0^p(t) = q_{01}(t) \oplus B_1^p(t) + q_{02}(t) \oplus B_2^p(t)$$

$$B_1^p(t) = W_1(t) + q_{10}(t) \oplus B_0^p(t) + q_{11.3}(t) \oplus B_1^p(t) + q_{12.6}(t) \oplus B_2^p(t)$$

$$B_2^p(t) = q_{20}(t) \oplus B_0^p(t) + q_{22.5}(t) \oplus B_2^p(t) + q_{24}(t) \oplus B_4^p(t)$$

$$B_4^p(t) = W_4(t) + q_{42}(t) \oplus B_2^p(t) \qquad (11)$$

where $W_1(t)$ and $W_4(t)$ be the probability that the server is busy in state S_1 and S_4 due to preventive maintenance up to time 't' without making any transition to any other regenerative state or returning to the same via one or more non-regenerative state and so

$$W_1(t) = \{e^{-(\alpha_0+\lambda)t} + (\alpha_0 e^{-(\alpha_0+\lambda)t} \oplus 1) + (\lambda e^{-(\alpha_0+\lambda)t} \oplus 1)\}\overline{F(t)} \text{ and } W_4(t) = \overline{F(t)} \qquad (12)$$

Taking Laplace transform of above relations (11 and 12) and solving for $B_0^{*p}(t)$. The time for which server is busy due to preventive maintenance is given by

$$B_0^P(t) = \lim_{s \to 0} sB_0^{*p}(t) = \frac{N_1^P}{D} \qquad (13)$$

Where

$$N_1^p(t) = W_1^*\big(p_{01}(1 - p_{22.5} - P_{24}P_{42}) + p_{24}W_4(P_{01}P_{12.6} + P_{02}(1 - P_{11.3})\big)$$

$$= \frac{\alpha\alpha_0 g^*(\lambda+\alpha_0)(1 - f^*(\lambda+\alpha_0))(1 - (\lambda+\alpha_0)g^{*\prime}(0)) + \lambda\alpha_0(1 - g^*(\lambda+\alpha_0))}{\alpha(\lambda+\alpha_0)^2}$$

and D has already mentioned in relation (10).

BUSY PERIOD ANALYSIS OF THE SERVER DUE TO REPAIR

Let $B_i^R(t)$ be the probability that the server is busy in repair of the unit at an instant 't' given that system entered state S_i at t=0. The recursive relations for $B_i^R(t)$ are as follows:

$$B_0^R(t) = q_{01}(t) \oplus B_1^R(t) + q_{02}(t) \oplus B_2^R(t)$$

$$B_1^R(t) = q_{10}(t) \oplus B_0^R(t) + q_{11.3}(t) \oplus B_1^R(t) + q_{12.6}(t) \oplus B_2^R(t)$$

$$B_2^R(t) = W_2(t) + q_{20}(t) \oplus B_0^R(t) + q_{22.5}(t) \oplus B_2^R(t) + q_{24}(t) \oplus B_4{}^R(t)$$

$$B_4^R(t) = q_{42}(t) \oplus B_2^R(t) \qquad (14)$$

where $W_2(t)$ is the probability that the server is busy in state S_2 respectively, due to repair up to time 't' without making any transition to any other regenerative state or returning to the same via one or more non-regenerative state and so

$$W_2(t) = e^{-(\alpha_0 t)}\, e^{(-\lambda t)}\, \overline{G(t)} \qquad (15)$$

Taking Laplace transform of above relations (14 and 15) and solving for $B_0^{*R}(t)$. We obtained. The time for which server is busy due to repair is given by

$$B_0^R(t) = \lim_{s \to 0} sB_0^{*R}(t) = \frac{N_2^R}{D}, \qquad (16)$$

Where

$$N_2^R(t) = W_2^*\{p_{01}p_{12.6} + p_{02}(1 - p_{11.3})\}$$

$$= \frac{\lambda(1 - g^*(\lambda+\alpha_0)(1 - (\lambda+\alpha_0)g^{*\prime}(0))}{(\lambda+\alpha_0)^3}$$

and D has already mentioned in relation (10).

EXPECTED NUMBER OF PREVENTIVE MAINTENANCES OF THE UNIT

Let $R_i^P(t)$ be the expected number of preventive maintenance of unit by the server in (0,t] given that the system entered the regenerative state S_i at t=0.

The recursive relations for $R_i^P(t)$ is given as

$$R_0^P(t) = Q_{01}(t) \otimes R_1^P(t) + Q_{02}(t) \otimes R_2^P(t)$$

$$R_1^P(t) = Q_{10}(t) \otimes [1 + R_0^P(t)] + Q_{11.3}(t) \otimes [1 + R_1^P(t)] + Q_{12.6}(t) \otimes [1 + R_2^P(t)]$$

$$R_2^P(t) = Q_{20}(t) \otimes R_0^P(t) + Q_{22.5}(t) \otimes R_2^P(t) + Q_{24}(t) \otimes R_4^P(t)$$

$$R_4^P(t) = Q_{42}(t) \otimes [1 + R_2^P(t)] \qquad (17)$$

Taking L.S.T of relations (17) and, solving for $\tilde{R}_0^P(t)$. The expected number of preventive maintenances per unit time are respectively of given by

$$R_0^P(\infty) = \lim_{s \to 0} s\tilde{R}_0^P(s) = \frac{N_3^P}{D} \qquad (18)$$

Where

$$N_3^P = p_{01}(1 - p_{22.5} - P_{24}P_{42}) + p_{24}P_{42}(p_{01}P_{12.6} + p_{02}(1 - p_{11.3}))$$

$$= \frac{\alpha_0(\lambda + \alpha_0 g^*(\lambda + \alpha_0))}{(\lambda + \alpha_0)^2}$$

and D has already defined in relation (10).

EXPECTED NUMBER OF REPAIR OF THE UNITS

Let $R_i^R(t)$ be the expected number of repairs of unit by the server in (0,t] given that the system entered the regenerative state S_i at t=0.

The recursive relations for $R_i^R(t)$ is given as

$$R_0^R(t) = Q_{01}(t) \otimes R_1^R(t) + Q_{02}(t) \otimes R_2^R(t)$$

$$R_1^R(t) = Q_{10}(t) \otimes R_0^R(t) + Q_{11.3}(t) \otimes R_1^R(t) + Q_{12.6}(t) \otimes R_2^R(t)$$

$$R_2^R(t) = Q_{20}(t) \otimes [1 + R_0^R(t)] + Q_{22.5}(t) \otimes [1 + R_2^R(t)] + Q_{24}(t) \otimes [1 + R_4^R(t)]$$

$$R_4^R(t) = Q_{42}(t) \otimes R_2^R(t)] \qquad (19)$$

Taking L.S.T of relations (19) and, solving for $\widetilde{R}_0^R(t)$ .The expected numbers of repairs per unit time are respectively given by

$$R_0^R(\infty) = \lim_{s \to 0} s\widetilde{R}_0^R(s) = \frac{N_4^R}{D} \qquad (20)$$

Where

$$N_4^R = \frac{\lambda}{(\lambda + \alpha_0)}$$

and D has already defined in relation (10).

PROFIT ANALYSIS

The profit incurred to the system model in steady state can be obtained as

$$P = K_0 A_0 - K_1 B_0^P - K_2 B_0^R - K_3 R_0^R - K_4 R_0^P - K_5 \qquad (21)$$

K_0= Revenue per unit up-time of the system

K_1= Cost per unit time for which server is busy due preventive maintenance

K_2= Cost per unit time for which server is busy due to repair

K_3= Cost per unit time repair

K_4= Cost per unit time preventive maintenances done by the server

K_5= Total installation cost of the system

PARTICULAR CASE

Let us take $g(t) = \theta e^{-\theta t}$ and $f(t) = \alpha e^{-\alpha t}$, then the following results are obtained:

$$\text{MTSF} = \frac{(\alpha + \lambda + \alpha_0)(\theta + \lambda + \alpha_0) + \alpha_0(\theta + \lambda + \alpha_0) + \lambda(\alpha + \lambda + \alpha_0)}{(\lambda + \alpha_0)(\alpha + \lambda + \alpha_0)(\theta + \lambda + \alpha_0) - \alpha\alpha_0(\theta + \lambda + \alpha_0) - \lambda\theta(\alpha + \lambda + \alpha_0)} \qquad (22)$$

Availability

$$A_0 = \frac{\alpha\theta(\lambda + \theta)(\alpha + \lambda + \alpha_0)}{\alpha\ \theta^2(\alpha + \lambda) + \alpha_0\theta^2(\alpha + \lambda + \alpha_0) + \lambda\alpha(\theta + \lambda)(\alpha + \lambda + \alpha_0) + \lambda{\alpha_0}^2\theta + \alpha_0\theta(\alpha_0 + \lambda)(\alpha + \lambda)} \qquad (23)$$

Busy period due to preventive maintenance

$$B_0^P = \frac{\alpha_0\theta(\lambda + \theta)(\alpha + \lambda + \alpha_0)}{\alpha\ \theta^2(\alpha + \lambda) + \alpha_0\theta^2(\alpha + \lambda + \alpha_0) + \lambda\alpha(\theta + \lambda)(\alpha + \lambda + \alpha_0) + \lambda{\alpha_0}^2\theta + \alpha_0\theta(\alpha_0 + \lambda)(\alpha + \lambda)} \qquad (24)$$

Busy period due to Repair

$$B_0^R = \frac{\alpha\lambda(\theta + \lambda)(\alpha + \lambda + \alpha_0)}{\alpha\ \theta^2\ (\alpha + \lambda) + \alpha_0\theta^2(\alpha + \lambda + \alpha_0) + \alpha\lambda(\theta + \lambda)(\alpha + \lambda + \alpha_0) + \lambda{\alpha_0}^2\theta + \alpha_0\theta(\alpha_0 + \lambda)(\alpha + \lambda)} \qquad (25)$$

Expected Number of visits by the server for conducting preventive maintenance

$$R_0^P = \frac{\alpha\alpha_0\theta(\lambda + \theta + \alpha_0)(\lambda + \theta)}{\alpha\ \theta^2\ (\alpha + \lambda) + \alpha_0\theta^2(\alpha + \lambda + \alpha_0) + \alpha\lambda(\theta + \lambda)(\alpha + \lambda + \alpha_0) + \lambda{\alpha_0}^2\theta + \alpha_0\theta(\alpha_0 + \lambda)(\alpha + \lambda)} \qquad (26)$$

Expected Number of visits by the server for doing repair

$$R_0^R = \frac{\lambda\alpha\ \theta(\alpha + \lambda + \alpha_0)(\theta + \lambda + \alpha_0)}{\alpha\ \theta^2\ (\alpha + \lambda) + \alpha_0\theta^2(\alpha + \lambda + \alpha_0) + \alpha\lambda(\theta + \lambda)(\alpha + \lambda + \alpha_0) + \lambda{\alpha_0}^2\theta + \alpha_0\theta(\alpha_0 + \lambda)(\alpha + \lambda)} \qquad (27)$$

DISCUSSION

First Curve of the figure 2 corresponding to L_2 (α_0=5, λ=0.01 and θ=3) represents that MTSF having increasing trend when the preventive maintenance rate 'α' is increasing between the range 5 to 14, third curve of this figure at its minimum range .38 to .56 corresponding to L_4 (α_0=5, λ=0.02 and θ=3). Similarly effect of the other parameters reflects from this figure. The graphical behaviour of mean time to system failure corresponding to preventive maintenance rate α, represents that L_3(α_0=7, λ=.01, θ=2.5) having increasing treand but at its lowest range, and the other parameters have very small impact on the MTSF with increasing trend.

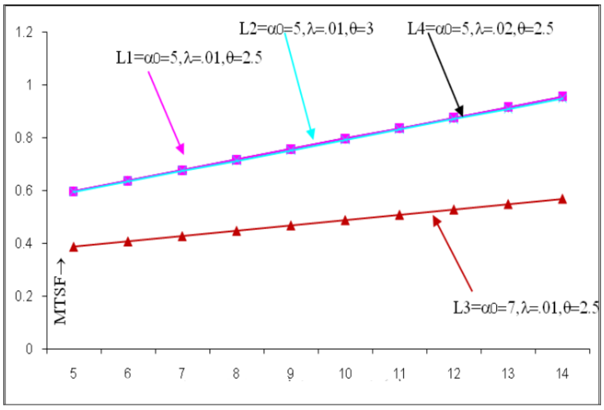


Figure 2: Premaintive Maintenance Rate (a)→

Figure 3 represents the graphical behavior of availability of the system with respect to the preventive maintenance rate α. The idea of preventive maintenance of the unit after a specific period of time can enhance the availability of the system. The curve L_1 (α_0=5, λ=0.01 and θ=2.5) coincide with the second curve corresponding to L_2 (α_0=5, λ=0.01 and θ=3) indicate that the effect of the parameter θ does not affect availability of the system at high level. The fourth curve L_4 (α_0=5, λ=0.02 and θ=3) corresponding to the parameter λ also having negligible impact on the availability of the system. Only α_0 is the parameter, which can affect on the availability of the system as shown in the curve L_3.

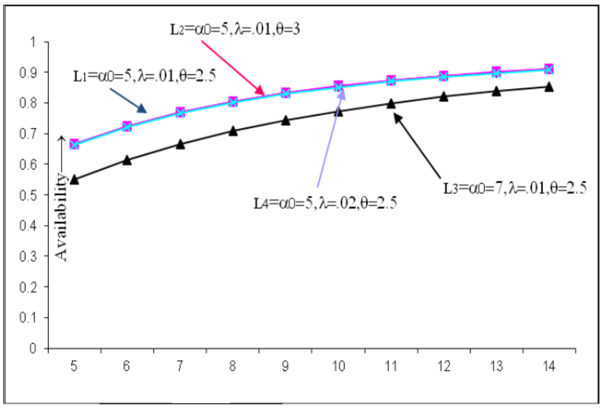


Figure 3: Preventive Maintenance Rate (a)→

Graphical behaviour of the profit of the system with respect to preventive maintenance of the unit α indicated in the figure 4, i.e profit of the system having increasing treand when the preventive maintenance rate α increases from 5 to 14.

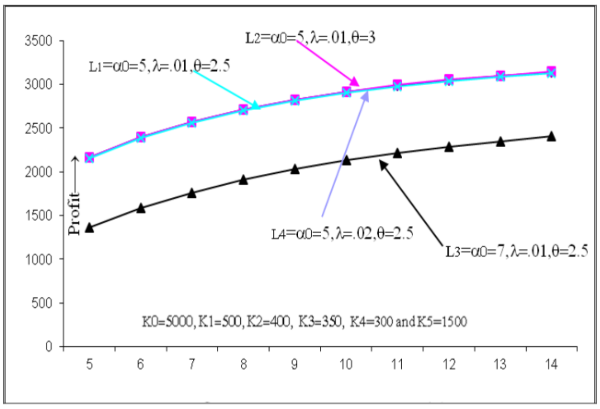


Figure 4: Preventive Maintenance Rate (a)→

Second curve of the figure having its maximum range (2159 to 3142). When the parameter α_0 increases from 5 to 7 then profit of the system at its lowest range but in increasing pettren between the range (1365 to 2401). Profit of any system is depends upon the availability of the sysem as well as MTSF of the system. Figure 4 represents the graphical behaviour of the profit of the system corresponding to preventive maintenance rate α. The curves L_1, L_2, and L_4 are coincide to each other corresponding to α_0=5, λ=0.01 and θ=2.5, θ=3 and λ=.02 respectively. And the curve L_3(α0=5, λ=0.01 and θ=2.5) at its lowest range as indicated in the graph.

CONCLUSION

The graphs for mean time to system failure, availability and profit function have been drawn with respect to preventive maintenance rate giving particular values to the parameters and costs as shown respectively in figures 2, 3 and 4. It is observed that the values of these reliability measures go on increasing with the increase of preventive maintenance and repair rates. However, their values decline with the increase of maximum constant rate of operation (α_0) and failure rate. Finally, it is concluded that the performance of a cold stand by system can be improved by conducting preventive maintenance after a pre-specific period of operation rather than increasing the repair rate of the system at its failure.

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