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RELIABILITY MEASURES OF A COLD STANDBY SYSTEM WITH PRIORITY FOR OPERATION AND PREVENTIVE MAINTENANCE

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ABSTRACT

In this paper reliability measures of a two-unit cold standby system are obtained considering the concepts of preventive maintenance and priority. The unit fails completely either directly from normal mode or via partial failure. There is a single server who visits the system immediately as and when needed. The preventive maintenance of the unit is done after a maximum operation time (MOT) at its partial failure stage. Priority is given for operation to new unit over the partially failed unit. Also, preventive maintenance (PM) of the unit is preferred over the repair. All random variables are statistically independent. The time to failure and maximum operation time are exponentially distributed whereas the distributions of PM and repair times are considered as arbitrary with different probability density functions. The system model has been analyzed using semi-Markov process and regenerative point technique. The behavior of MTSF, availability and profit incurred to the system model is observed for particular values of various parameters and costs.

Keywords: *Cold Standby System, Priority, Preventive Maintenance, Maximum Operation Time and Reliability Measures.*

2000 Mathematics Subject Classification: *90B25, 60K10.*

INTRODUCTION

Most of the reliability models suggested for maintained systems have been analyzed stochastically in detail by the researchers including [1-3] under a common assumption that operating unit enters directly into the complete failed state with constant failure rate. However, in practice there are many situations where a unit works in various degraded stages before its total failure and thus it may fail completely either directly or via partial failure. Therefore, preventive maintenance of such systems becomes necessary after a maximum operation time at any stage of failure not only to improve the performance but also to enhance the reliability of the system. Singh and Agarafiotis [1995] and Malik *et al.* [2009] studied systems under preventive maintenance after a specific period of operation. But the concept of preventive maintenance after a maximum operation time at partial failure stage has not been introduced so far in the literature of reliability.

Also, the profit of a system may further be increased by assigning priority for operation to new unit over the partially failed unit. Kadyan *et al.* [2010] have made stochastic analysis of a redundant system considering the idea of priority for operation to new unit over the degraded unit. Moreover, there are many situations in which priority for preventive maintenance and repair over each other is required.

In view of the above, here reliability measures of a cold standby system of two identical units are evaluated considering the concepts of preventive maintenance and priority in both operation and repair activities. Each unit fails completely either directly from normal mode or via partial failure. There is a single server who visits the system immediately to carry out preventive maintenance and repair. The preventive maintenance of the unit is done after a maximum operation time (MOT) at its partial failure stage. The priority for operation to new unit is given over the partially failed unit. The preventive maintenance of the unit is preferred over the repair. All random variables are statistically independent. The distributions of failure and operation times follow negative exponential while that of preventive maintenance and repair times are considered as arbitrary with different probability density functions. The unit works as good as new after preventive maintenance and repair. The unit under preventive maintenance does not work and repair of the unit is done only at its complete failure. The switch devices are assumed as perfect. The expressions for some measures of system effectiveness such as transition probabilities, mean sojourn times, mean time to system failure (MTSF), availability in steady state, busy period of the server due to PM and repair, expected number of visits by the server and the profit incurred to the system model are derived using semi-Markov process and regenerative point technique. The behavior of MTSF, availability and profit has also been observed on the basis of the numerical results obtained for a particular case.

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2. NOTATION

E_0 : The state of the system at t = 0
E : The set of regenerative states
O : The unit is operative and in normal mode
Cs : The unit is in cold standby
λ : Constant complete failure rate of the unit from normal mode
λ_1 : Constant failure rate of the unit from normal mode to partial failure
λ_2 : Constant failure rate of the unit from partial to complete failure
α_0 : Maximum constant rate of operation after partial failure
Pm / PM : Unit under preventive maintenance / preventive maintenance is continued from previous state
WPm : Unit is waiting for preventive maintenance
Fwr/ FUr/ : Unit is failed and waiting for repair / under repair / under FURrepair continuously from previous state
PFO/PFS : Unit is partially failed and operative/ in cold standby
f(t) / F(t): pdf/cdf of the time for preventive maintenance
g(t) / G(t) : pdf / cdf of the time for repair of the completely failed unit
$q_{ij}(t)$ / $Q_{ij}(t)$: pdf / cdf of transition time from Si to Sj
$q_{ij.kr}(t)$/$Q_{ij.kr}(t)$: pdf / cdf of transition time from regenerative state i to a regenerative state j or to a failed state j visiting state k, r once in (0, t]
μ_I : Probability that the system up initially in state $S_i \in E$ is up at time t without visiting to any regenerative state
m_{ij} : Contribution to mean sojourn time in state S_i when system transits directly to state S_j (S_i , $S_j \in E$) and is given by $m_{ij} = \int q_{ij}(t)dt = \int dQ_{ij}(t) = -\left[\frac{d}{ds}\left(Q^*_{ij}(s)\right)\right]_{s=0}$ and $\mu_i = \sum_j m_{ij}$, where μ_i is the mean sojourn time in state $S_i \in E$
pdf / cdf : Probability density function / cumulative distribution function
LST/LT : Laplace Stieltjes transform / Laplace transform
~ / * : Symbol for Laplace Stieltjes transform / Laplace transform
Ⓢ / © : Symbol for Stieltjes convolution / Laplace convolution
' (dash) : Symbol for derivative of the function
$W_i(t)$: Probability that the server is busy in the state S_i upto time 't' without making any transition to any other regenerative state or returning to the same state via one or more non-regenerative states.

The state transition diagram for the system model is shown in figure 1.

3. TRANSITION PROBABILITIES AND MEAN SOJOURN TIMES

Simple probabilistic considerations yield the following expressions for non-zero elements $p_{ij} = Q_{ij}(\infty) = \int q_{ij}(t)dt$ as

$$p_{01} = p_{15} = \frac{\lambda_1}{\lambda+\lambda_1},$$

$$p_{02} = p_{14} = \frac{\lambda}{\lambda+\lambda_1},$$

$$p_{20} = g^*(\lambda+\lambda_1),$$

$$p_{27} = \frac{\lambda_1}{\lambda+\lambda_1}\left[1-g^*\left(\lambda+\lambda_1\right)\right] \quad ,$$

$$p_{28} = \frac{\lambda}{\lambda+\lambda_1}\left[1-g^*\left(\lambda+\lambda_1\right)\right],$$

$$p_{30} = f^*\left(\lambda+\lambda_1\right),$$

$$p_{3,10} = \frac{\lambda_1}{\lambda+\lambda_1}\left[1-f^*\left(\lambda+\lambda_1\right)\right],$$

$$p_{3,11} = \frac{\lambda}{\lambda+\lambda_1}\left[1-f^*\left(\lambda+\lambda_1\right)\right],$$

$$p_{41} = p_{71} = g^*\left(\lambda_2+\alpha_0\right),$$

$p_{48} = p_{78} = \frac{\lambda_2}{\lambda_2+\alpha_0}\left[1-g^*\left(\lambda_2+\alpha_0\right)\right]$,

$p_{49} = p_{79} = \frac{\alpha_0}{\lambda_2+\alpha_0}\left[1-g^*\left(\lambda_2+\alpha_0\right)\right]$,

$p_{54} = \frac{\lambda_2}{\lambda_2+\alpha_0}$,

$p_{56} = \frac{\alpha_0}{\lambda_2+\alpha_0}$,

$p_{61} = p_{10,1} = f^*\left(\lambda_2+\alpha_0\right)$,

$p_{6,11} = p_{10,11} = \frac{\lambda_2}{\lambda_2+\alpha_0}\left[1-f^*\left(\lambda_2+\alpha_0\right)\right]$,

$p_{6,12} = p_{10,12} = \frac{\alpha_0}{\lambda_2+\alpha_0}\left[1-f^*\left(\lambda_2+\alpha_0\right)\right]$, $p_{82} = g^*(0)$,

$p_{92} = p_{11,2} = p_{12,3} = f^*(0)$ (1)

It can be easily verified that

$p_{01} + p_{02} = p_{14} + p_{15} = p_{20} + p_{27} + p_{28} = p_{30} + p_{3,11} + p_{3,12} = p_{41} + p_{48} + p_{49} = p_{54} + p_{56}$
$= p_{61} + p_{6,11} + p_{6,12} = p_{71} + p_{78} + p_{79} = p_{82} = p_{92}$
$= p_{10,1} + p_{10,11} + p_{10,12} = p_{11,2} = p_{12,3} = 1$ (2)

The mean sojourn times in the state S_i is given by

$$\mu_i = E(T) = \int_0^\infty P(T>t)dt \tag{3}$$

where T denotes the time to system failure.

Using these, we have

$\mu_0 = m_{01} + m_{02}$,
$\mu_1 = m_{14} + m_{15}$,
$\mu_2 = m_{20} + m_{27} + m_{28}$,
$\mu_3 = m_{30} + m_{3,10} + m_{3,11}$,
$\mu_4 = m_{41} + m_{48} + m_{49}$,
$\mu_5 = m_{54} + m_{56}$,
$\mu_6 = m_{61} + m_{6,11} + m_{6,12}$,
$\mu_7 = m_{71} + m_{78} + m_{79}$,
$\mu_8 = m_{82}, \mu_9 = m_{92}$,
$\mu_{10} = m_{10,1} + m_{10,11} + m_{10,12}$,
$\mu_{11} = m_{11,2}$,
$\mu_{12} = m_{12,3}$ (4)

4. RELIABILITY AND MEAN TIME TO SYSTEM FAILURE (MTSF)

Let $\phi_i(t)$ be the cdf of the first passage time from regenerative state i to a failed state. Regarding the failed state as absorbing state, we have the following recursive relations for $\phi_i(t)$:

$$\varphi_i(t) = \sum_j Q_{i,j}(t)\ (S)\varphi_j(t) + \sum_k Q_{i,k}(t) \tag{5}$$

where *j* is an un-failed regenerative state to which the given regenerative state *i* can transit and *k* is a failed state to which the state *i* can transit directly. Taking LST of above relations (5) and solving for $\tilde{\phi}_0(s)$, we have

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

The reliability R(t) of the model can be obtained by taking Laplace inverse transform of (6).

The mean time to system failure (MTSF) is given by

$$\text{MTSF } (T_1) = \lim_{s\to 0} R^*(s) = \frac{N_1}{D_1}, \tag{7}$$

where

$N_1 = [1-p_{15}p_{56} - p_{41}(p_{14} + p_{15}p_{54})][\mu_0 + p_{02}(\mu_2 + p_{27}\mu_7)] + (p_{01}+p_{02}p_{27}p_{71})[\mu_1(p_{14}+p_{15}p_{54})\mu_4 + p_{15}(\mu_5+p_{56}\mu_6)]$

and $D_1 = (1- p_{02}p_{20})[1- p_{15}p_{56}p_{61} - p_{41}(p_{14}+ p_{15}p_{54})]$

5. STEADY STATE AVAILABILITY

Let $A_i(t)$ be the probability that the system is in upstate at instant 't' given that the system entered regenerative state i at t = 0.

The recursive relations for $A_i(t)$ are given as

$$A_i(t) = M_i(t) + \sum_j q_{i,j}^{(n)}(t) © A_j(t) \tag{8}$$

where j is any successive regenerative state to which the regenerative state i can transit through n transitions. $M_i(t)$ 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

where

$M_0(t) = M_1(t) = e^{-(\lambda+\lambda_1)t}$, $M_2(t) = e^{-(\lambda+\lambda_1)t}\overline{G}(t)$, $M_3(t) = e^{-(\lambda+\lambda_1)t}\overline{F}(t)$,

$M_4(t) = e^{-(\lambda_2+\alpha_0)}\overline{G}(t)$, $M_5(t) = e^{-(\lambda_2+\alpha_0)t}$, $M_6(t) = e^{-(\lambda_2+\alpha_0)}\ \overline{F}(t)$

Taking LT of above relations (8) and solving for $A_0^*(s)$. Using this, the steady-state availability is given as

$$A_{10} = \lim_{s\to 0} sA_0^*(s) = \frac{N_2}{D_2} \text{ ,where} \tag{9}$$

$N_2 = [p_{20}(1 - p_{3,10}p_{10,12})(1-p_{14}p_{41}-p_{15}p_{54}p_{41} - p_{15}p_{56}p_{61}) + p_{15}p_{56}p_{6,12}(p_{27}p_{71}p_{30} - p_{20}p_{3,10}p_{10,1})]\mu_1$
$\quad + (p_{01}p_{20} + p_{27}p_{71})[(1 - p_{3,10}p_{10,12})\{\mu_1 + (p_{14} + p_{15}p_{54})\mu_4 + p_{15}\mu_5 + p_{15}p_{56}\mu_6\} + p_{15}p_{56}p_{6,12}\mu_3]$
$\quad + [(1 - p_{3,10}p_{10,12})(1-p_{14}p_{41}-p_{15}p_{54}p_{41}) + p_{15}p_{56}\{p_{01}p_{6,12}(p_{3,11} + p_{3,10}p_{10,11})$
$\quad + p_{01}p_{6,11}(1 - p_{3,10}p_{10,12}) - p_{02}p_{3,10}p_{10,1}p_{6,12} - p_{02}p_{61}(1 - p_{3,10}p_{10,12})\}]\mu_2$

$D_2 = [p_{20}(1 - p_{3,10}p_{10,12})(1-p_{14}p_{41}-p_{15}p_{54}p_{41} - p_{15}p_{56}p_{61}) + p_{15}p_{56}p_{6,12}(p_{27}p_{71}p_{30} - p_{20}p_{3,10}p_{10,1})]\mu_0$
$\quad + (p_{01}p_{20} + p_{27}p_{71})[(1 - p_{3,10}p_{10,12})\{\mu_1 + (p_{14} + p_{15}p_{54})\mu'_4 + p_{15}\mu_5 + p_{15}p_{56}\mu'_6\} + p_{15}p_{56}p_{6,12}\mu'_3]$
$\quad + [(1 - p_{3,10}p_{10,12})(1-p_{14}p_{41}-p_{15}p_{54}p_{41}-p_{15}p_{56}p_{61}) - p_{15}p_5p_{6,12}(p_{01}p_{30} + p_{3,10}p_{10,1})]\mu'_2$
$\quad + [(1 - p_{3,10}p_{10,12})\{p_{27}p_{79}(1-p_{14}p_{41}-p_{15}p_{54}p_{41}-p_{15}p_{56}p_{61}) + p_{49}(p_{01}p_{20} + p_{27}p_{71})(p_{14}+p_{15}p_{54})\}$
$\quad + p_{27}p_{79}p_{15}p_{56}p_{6,12}(p_{01}p_{30} - p_{3,10}p_{10,1})]\mu_9$

and

$\mu_2^1 = m_{20} + m_{21.7} + m_{22.8} + m_{22.78} + m_{29.7}$, $\mu_3^1 = m_{30} + m_{31.10} + m_{32.11} + m_{32.10,11} + m_{33.10,12}$, $\mu_4^1 = m_{41} + m_{42.8} + m_{49}$

and $\mu_6^1 = m_{61} + m_{62.11} + m_{63.12}$

6. BUSY PERIOD ANALYSIS OF THE SERVER DUE TO REPAIR AND MAINTENANCE

Let $B_i^1(t)$ and $B_i^2(t)$ be the probability that the server is busy respectively in repairing and preventive maintenance of the unit at an instant 't' given that the system entered regenerative state i at t = 0. The recursive relations for $B_i^1(t)$ and $B_i^2(t)$ are respectively given as

$$B_i^1(t) = W_i(t) + \sum_j q_{i,j}^{(n)}(t) © B_j^1(t) \tag{10}$$

$$B_i^2(t) = W_i(t) + \sum_j q_{i,j}^{(n)}(t) © B_j^2(t) \tag{11}$$

where *j* is any successive regenerative state to which the regenerative state *i* can transit through n transitions. Let $W_i(t)$ be the probability that the server is busy in state S_i due to repair and 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 states . Also, we have

W_2 (t) = $e^{-(\lambda+\lambda_1)t}\bar{G}(t)+\left(\lambda e^{-(\lambda+\lambda_1)t}©1\right)\bar{G}(t)+\left(\lambda_1 e^{-(\lambda+\lambda_1)t}©1\right)\bar{G}(t)$,

W_4 (t) = $e^{-(\lambda_2+\alpha_0)t}\bar{G}(t)+\left(\lambda_2 e^{-(\lambda_2+\alpha_0)t}©1\right)\bar{G}(t)$

W3 (t) = $e^{-(\lambda+\lambda_1)t}\bar{F}(t)+\left(\lambda e^{-(\lambda+\lambda_1)t}©1\right)\bar{F}(t)+\left(\lambda_1 e^{-(\lambda+\lambda_1)t}©1\right)\bar{F}(t)$,

W_6 (t) = $e^{-(\lambda_2+\alpha_0)t}\bar{F}(t)+\left(\lambda_2 e^{-(\lambda_2+\alpha_0)t}©1\right)\bar{F}(t)+\left(\alpha_0 e^{-(\lambda_2+\alpha_0)t}©1\right)\bar{F}(t)$

W_9 (t) = $\bar{F}(t)$

Taking LT of above relations (10) and (11). Solving for B_0^{1*} (s) and B_0^{2*} (s), we get in the long run the time for which the system is under repair and preventive maintenance respectively as

$$B_{10}^1=\lim_{s\to 0} sB_0^{1*}(s)=\frac{N_3}{D_2}$$

$$B_{10}^2=\lim_{s\to 0} sB_0^{2*}(s)=\frac{N_4}{D_2} \tag{12}$$

where,

N_3 = [(1 - $p_{3,10}p_{10,12}$) (1-$p_{14}p_{41}$-$p_{15}p_{54}p_{41}$) + $p_{15}p_{56}${$p_{01}p_{6,12}$($p_{3,11}$ + $p_{3,10}p_{10,11}$) + $p_{01}p_{6,11}$(1 - $p_{3,10}p_{10,12}$)
- $p_{02}p_{3,10}p_{10,1}p_{6,12}$ - $p_{02}p_{61}$(1 - $p_{3,10}p_{10,12}$)}] $W_2^*(0)$
+ (1 - $p_{3,10}p_{10,12}$) ($p_{01}p_{20}$ + $p_{27}p_{71}$) (p_{14} + $p_{15}p_{54}$) $W_4^*(0)$

N_4 = $p_{15}p_{56}p_{6,12}$ ($p_{01}p_{20}$ + $p_{27}p_{71}$)$W_3^*(0)$+ $p_{15}p_{56}$(1- $p_{3,10}p_{10,12}$) ($p_{01}p_{20}$ + $p_{27}p_{71}$)$W_6^*(0)$+ [(1- $p_{3,10}p_{10,12}$) (p_{14}+$p_{15}p_{54}$){$p_{01}p_{49}$(1- p_{28} - $p_{27}p_{78}$) + $p_{01}p_{48}p_{27}p_{79}$ + $p_{02}p_{27}$($p_{71}p_{49}$ – $p_{79}p_{41}$)}+ $p_{15}p_{56}p_{27}p_{79}${$p_{01}p_{6,12}$($p_{3,11}$+$p_{3,10}p_{10,11}$) + (1- $p_{3,10}p_{10,12}$) ($p_{01}p_{6,11}$ - $p_{02}p_{61}$) - $p_{02}p_{3,10}p_{10,1}p_{6,12}$}]$W_9^*(0)$ and D_2 is already specified.

7. EXPECTED NUMBER OF VISITS BY THE SERVER

Let N_i (t) be the expected number of visits by the server in (0, t] given that the system entered the regenerative state i at t = 0. The recursive relations for $N_i(t)$ are given as

$$N_i(t)=\sum_j Q_{i,j}^{(n)}(t)(S)\left[\delta_j+N_j(t)\right] \tag{13}$$

where j is any regenerative state to which the given regenerative state *i* transits and δj =1, if *j* is the regenerative state where the server does job afresh, otherwise δj = 0. Taking LT of relation (13) and solving for $\tilde{N}_0(s)$. The expected numbers of visits per unit time by the server are given

$$N_{10}=\lim_{s\to 0} s\tilde{N}_0(s)=\frac{N_5}{D_2} \tag{14}$$

where,

N_5 = p_{02}[p_{20}(1- $p_{3,10}p_{10,12}$) (1-$p_{14}p_{41}$-$p_{15}p_{54}p_{41}$-$p_{15}p_{56}p_{61}$) + $p_{15}p_{56}p_{6,12}$ ($p_{27}p_{71}p_{30}$ - $p_{20}p_{3,10}p_{10,1}$)]
+ (1- $p_{3,10}p_{10,12}$) ($p_{01}p_{20}$+$p_{27}p_{71}$)

and D_2 is already specified.

9. PROFIT ANALYSIS

Profit incurred to the system model in steady state is given by

$$P_i = K_1A_{10} - K_2 B_{10}^{1} - K_3 B_{10}^{2} - K_4 N_{10} \qquad (15)$$

where

K_1 = Revenue per unit up-time of the system
K_2 = Cost per unit time for which server is busy in repair
K_3 = Cost per unit time for which server is busy in preventive maintenance
K_4 = Cost per unit visit by the server

State Transition Diagram

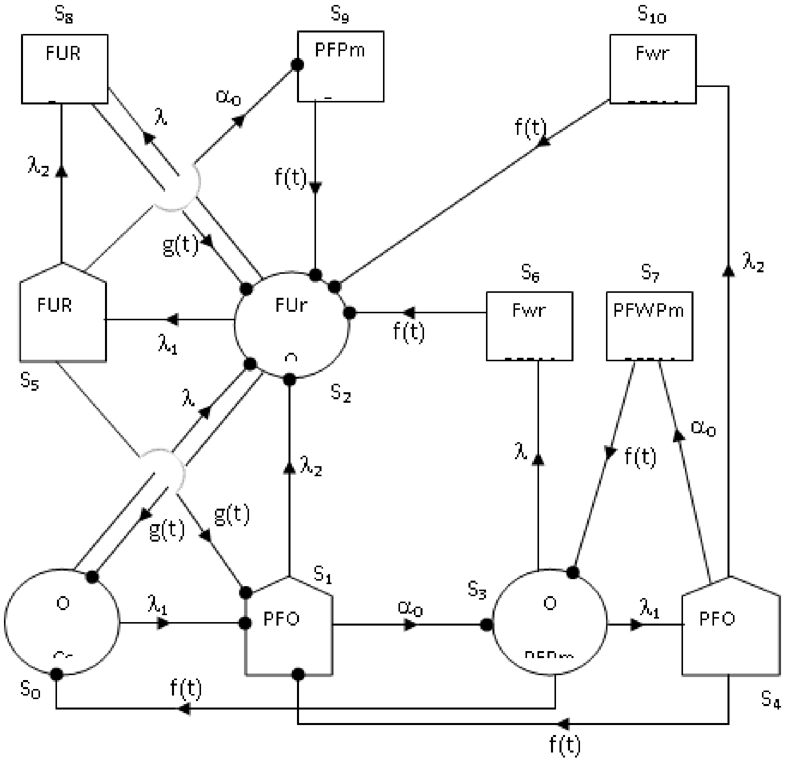

Fig. 1

• Regenerative point ○ Up-state □ Failed state ⌂ Partial failure up-state

10. PARTICULAR CASE

For particular case g(t) = $\theta e^{-\theta t}$, f(t) = $\beta e^{-\beta t}$, the following results are obtained giving arbitrary values to various parameters and costs.

Table-1

α_0 ↓	Mean Time to System Failure(MTSF)				
	λ=.13,λ1=.17, λ2=.21,θ=2.1, β=2.7	λ=.16,λ1=.17, λ2=.21,θ=2.1, β=2.7	λ=.13,λ1=.20, λ2=.21,θ=2.1, β=2.7	λ=.13,λ1=.17, λ2=.21,θ=2.6, β=2.7	λ=.13,λ1=.17, λ2=.21,θ=2.1, β=3.7
5	7.588071	7.22887	6.670627	7.731869	8.051282
10	6.56007	6.32531	5.693827	6.651233	6.823007
15	6.209871	6.016065	5.362984	6.288034	6.394234
20	6.033109	5.85966	5.196402	6.105867	6.175197
25	5.926476	5.765199	5.096049	5.996381	6.042101
30	5.855135	5.701955	5.028971	5.923313	5.952622
35	5.804049	5.656644	4.980968	5.871083	5.888324
40	5.765664	5.622584	4.944915	5.83189	5.839884
45	5.□35765	5.596046	4.916844	5.801393	5.802076
50	5.711819	5.574787	4.894368	5.776988	5.771744

Table-2

α_0	Availability				
	λ=.13,λ1=.17, λ2=.21,θ=2.1, β=2.7	λ=.16,λ1=.17, λ2=.21,θ=2.1, β=2.7	λ=.13,λ1=.20, λ2=.21,θ=2.1, β=2.7	λ=.13,λ1=.17, λ2=.21,θ=2.6, β=2.7	λ=.13,λ1=.17, λ2=.21,θ=2.1, β=3.7
5	0.961356	0.958111	0.956514	0.963456	0.971081
10	0.958597	0.955382	0.953191	0.960371	0.968948
15	0.957604	0.954415	0.951989	0.959244	0.968164
20	0.957094	0.953923	0.951372	0.958662	0.967757
25	0.956785	0.953626	0.950997	0.958308	0.967509
30	0.956577	0.953427	0.950745	0.95807	0.967342
35	0.956428	0.953284	0.950565	0.957898	0.967222
40	0.956316	0.953177	0.950429	0.957769	0.967131
45	0.956229	0.953094	0.950323	0.957669	0.967061
50	0.956159	0.953027	0.950238	0.957588	0.967004

Table-3

α_0	Profit				
	λ=.13,λ1=.17, λ2=.21,θ=2.1, β=2.7,K1=5000, K2=150,K3=75, K4=50	λ=.16,λ1=.17, λ2=.21,θ=2.1, β=2.7,K1=5000, K2=150,K3=75, K4=50	λ=.13,λ1=.20, λ2=.21,θ=2.1, β=2.7,K1=5000, K2=150,K3=75, K4=50	λ=.13,λ1=.17, λ2=.21,θ=2.6, β=2.7,K1=5000, K2=150,K3=75, K4=50	λ=.13,λ1=.17, λ2=.21,θ=2.1, β=3.7,K1=5000, K2=150,K3=75, K4=50
5	4781.639	4762.868	4755.688	4793.801	4831.945
10	4766.102	4747.478	4736.809	4776.588	4820.826
15	4758.62	4740.278	4727.736	4768.413	4815.617
20	4753.451	4735.384	4721.471	4762.856	4812.18
25	4749.256	4731.451	4716.386	4758.407	4809.502
30	4745.562	4728.009	4711.906	4754.528	4807.217
35	4742.158	4724.85	4707.778	4750.98	4805.162
40	4738.937	4721.871	4703.872	4747.642	4803.253
45	47□5.84	4719.011	4700.116	4744.446	4801.442
50	4732.829	4716.235	4696.464	4741.349	4799.7

11. CONCLUSION

It is observed that mean time to system failure (MTSF), availability and profit go on decreasing with the increase of maximum operation time and failure rates (λ and λ_1) for fixed values of other parameters as shown respectively in tables 1, 2 and 3. But the values of these measures increase with the increase of repair rate (θ) and preventive maintenance rate (β). Thus on the basis of numerical results obtained for a particular case, it is concluded that the concepts of priority for operation to new unit over partially failed unit and the preference of preventive maintenance over repair are more economically beneficial as compared to the system in which no such priority is given. However, there is no effect of such a priority on MTSF.

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