Journal of Reliability and Statistical Studies; ISSN (Print): 0974-8024, (Online): 2229-5666
Vol. 9, Issue 2 (2016): 17-27

COST-BENEFIT ANALYSIS OF A SYSTEM OF NON-IDENTICAL UNITS UNDER PREVENTIVE MAINTENANCE AND REPLACEMENT

S.C. Malik and *Upma
Department of Statistics, M.D. University, Rohtak, India
E Mail: sc_malik@rediffmail.com; *upma82@yahoo.in

Received January 13, 2016
Modified September 30, 2016
Accepted November 05, 2016

Abstract

A stochastic model for a system of two non-identical units is developed by considering all random variables statistically independent. Initially, the main unit (original) is operative while the other unit (duplicate) is kept as spare in cold standby. Each unit has two modes – operative and complete failure. A single server is provided immediately to handle the faults which occur during operation of the system. The maintenance and repair of the main unit are carried out whenever needed. However, replacement of the duplicate unit is made by new one after its failure. The failure time and the time by which unit undergoes for preventive maintenance and replacement follow negative exponential distribution, whereas the distributions for preventive maintenance, repair and replacement rates are taken as arbitrary with different probability density functions. Some reliability measures of vital significance are obtained in steady state using semi-Markov process and regenerative point technique. The cost - benefit analysis of the system model has been done for arbitrary values of the parameters. The graphical behavior of some important reliability measures including profit function has been observed.

Key Words: Non-identical Units, Preventive Maintenance, Replacement, Reliability Measures, Cost- Benefit Analysis.

1. Introduction

The stochastic modeling of redundant systems with identical units has been done at large scale by the researchers due to their practical utility in industries and management sectors. The reliability measures of these systems have been obtained by considering different failure and repair policies. Cao and Wu (1989), Dhillon (1992) and Kumar et al. (2012) obtained reliability measures of standby systems of identical units under different sets of assumptions on failure and repair laws. But, there exist many systems in which non-identical components may be perfered due to reduced over all manufactring and operating costs. Goel et al. (1996) proposed a stochastic model for a two unit duplicating standby system with correlated failure-repair times. Malik et al. (2013) analyzed a system of non-identical units operating under different weather conditions. It is proved that preventive maintenance is one of the effective techniques to reduce deterioration rate of repairable systems operating under varying envionmenatal conditions. Malik and Barak (2013) evaluated reliability measures of a cold standby system with preventive maintenance and repair. Also, Rathee and Chander (2014) discussed a parallel system with the concepts of priority and preventive maintenance. Further, some times repair of a sub standard unit is not benificial due to its exessive use and so in such a situation, the unit may be replaced by new one in order to avoid unnecessary expansses on repair. Dhall et al. (2014) investigated a standby system with possible maintenance and replacement of faild unit.

The present paper deals with the cost benefit analysis of a system of non-identical units under the aspects of preventive maintenance and replacement. There are two modes of each unit-operating and complete failure. Initially, the main unit (original) is operative and the other unit (duplicate) is taken as spare in cold standby. There is a single server who visits the system immediately to rectify faults which occur during operation of the system. The main unit undergoes for preventive maintenance after a pre-specific time of operation. However, duplicate unit is replaced by new one at its failure while original is repaired at its failure. All the random variables are statistically independent. The failure time and the time by which unit undergoes for preventive maintenance and replacement follow negative exponential distribution, whereas the distributions for preventive maintenance, repair and replacement rates are taken as arbitrary with different probability density functions. Various reliability and performance measures are obtained in steady state using semi-Markov process and regenerative point technique. The graphical behavior of the MTSF, availability and profit function has been observed for a particular case.

2. Notations

E	:	Set of regenerative states
$\bar{E}$	:	Set of non-regenerative states
λ / $\lambda 1$	:	Constant failure rate of the original (main) unit/ duplicate unit
α_0	:	The rate by which system undergoes for preventive maintenance
Mo/Do	:	Main/Duplicate unit is good and operative
MCs /DCs	:	Main/Duplicate unit is in cold standby mode
MFUr /MFWr	:	The main unit is failed and under repair/waiting for repair
DFURp	:	The duplicate unit is failed and under replacement
MPm	:	The main unit is under preventive maintenance
MWPm	:	The main unit is waiting for preventive maintenance
DFWRp	:	The duplicate unit is failed and waiting for replacement
MFUR	:	The main unit is failed and under repair for repair continuously from previous state
DFURP	:	The duplicate unit is failed and under replacement continuously from previous state
MPM	:	The unit is under preventive maintenance continuously from previous state
MWPm	:	The unit is waiting for preventive maintenance continuously from previous state
g(t)/G(t)	:	pdf/cdf of repair time of the unit
f(t)/F(t)	:	pdf/cdf of preventive maintenance time of the unit
r(t)/R(t)	:	pdf/cdf of replacement time of the unit
$q_{ij}(t)/Q_{ij}(t)$	:	pdf /cdf of passage time from regenerative state S_i to a regenerative state S_j

$q_{ij.kr}(t)/Q_{ij.kr}(t)$	:	pdf/cdf of direct transition time from regenerative state Si to a regenerative state S_j or to a failed state S_j visiting state S_k, Sr once in (0, t]
$M_i(t)$	:	Probability that the system up initially in state $S_i \in E$ is up at time t without visiting to any regenerative state.
$W_i(t)$	:	Probability that the server is busy in the state Si up to time 't' without making any transition to any other regenerative state or returning to the same state via one or more non-regenerative states.
m_{ij}	:	Contribution to mean sojourn time (μ_i) in state S_i when system transits directly to state S_j so that $\mu_i = \sum_j m_{ij}$ and $m_{ij} = \int t dQ_{ij}(t) = -q_{ij}^{*'}(0)$
Ⓢ/©	:	Symbol for Laplace-Stieltjes convolution/Laplace convolution
*/**	:	Symbol for Laplace Transformation /Laplace Stieltjes Transformation

The possible transition states are shown in figure 1.

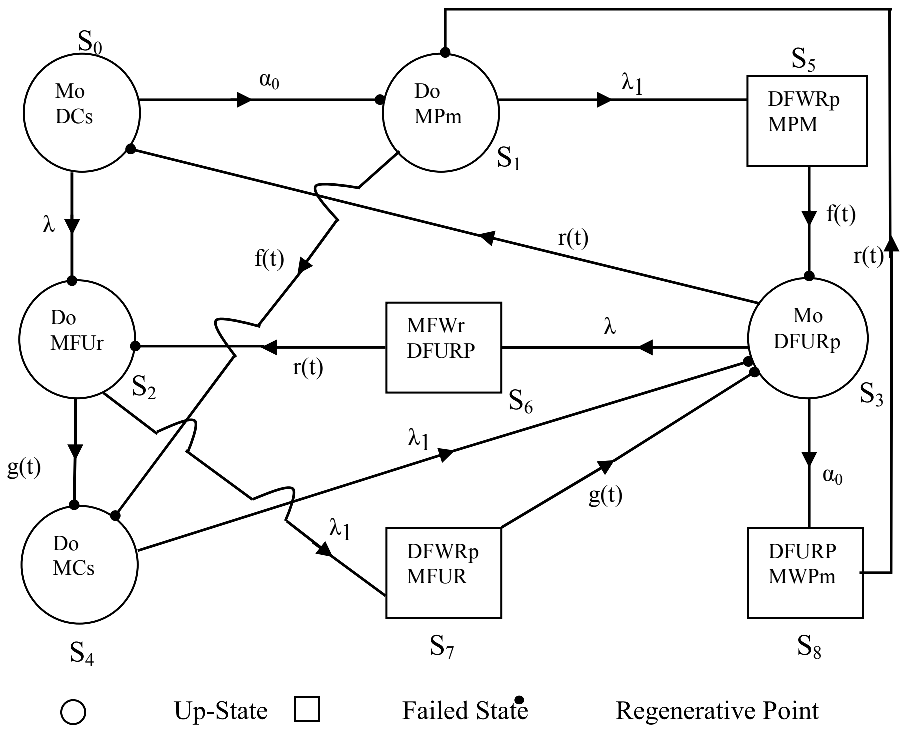

Fig. 1: Transition State Diagram

3. Transition Probabilities and Mean Sojourn Times

Simple probabilistic considerations yield the following expressions for the non-zero elements $p_{ij} = Q_{ij}(\infty) = \int_0^\infty q_{ij}(t)dt$ (1)

We have

$p_{01} = \frac{\alpha_0}{\alpha_0+\lambda}, p_{02} = \frac{\lambda}{\alpha_0+\lambda}$, $p_{15} = 1 - f^*(\lambda_1)$, $p_{14} = f^*(\lambda_1)$

$p_{24} = g^*(\lambda_1)$, $p_{27} = 1 - g^*(\lambda_1)$, $p_{30} = r^*(\alpha_0 + \lambda), p_{13.5} = 1 - f^*(\lambda_1)$

$p_{38} = \frac{\alpha_0}{\alpha_0+\lambda}(1 - r^*(\alpha_0 + \lambda))$, $p_{36} = \frac{\lambda}{\alpha_0+\lambda}(1 - r^*(\alpha_0 + \lambda))$

$p_{31.8} = \frac{\alpha_0}{\alpha_0+\lambda}(1 - r^*(\alpha_0 + \lambda))$, $p_{32.6} = \frac{\lambda}{\alpha_0+\lambda}(1 - r^*(\alpha_0 + \lambda))$

$p_{23.7} = 1 - g^*(\lambda_1), p_{53} = p_{73} = p_{62} = p_{81} = p_{43} = 1$ (2)

It can be easily verify that

$p_{01} + p_{02} = p_{14} + p_{15} = p_{27} + p_{24} = p_{36} + p_{38} + p_{30} = p_{53} = p_{73} = p_{62} = p_{43} = p_{81} = 1$

$p_{14} + p_{13.5} = p_{24} + p_{23.7} = p_{30} + p_{32.6} + p_{31.8} = 1$

The mean sojourn times (μ_i) is in the state S_i are

$\mu_0 = m_{01} + m_{02}$, $\mu_1 = m_{14} + m_{15}$, $\mu_3 = m_{30} + m_{36} + m_{38}$

$\mu_4 = m_{43}$, $\mu_1' = m_{14} + m_{13.5}$, $\mu_2' = m_{24} + m_{23.7}$

$\mu_3' = m_{30} + m_{32.6} + m_{31.8}$ (3)

4. Reliability and Mean Time to System Failure (MTSF)

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

$\phi_0(t) = Q_{01}(t) Ⓢ \phi_1(t) + Q_{02}(t) Ⓢ \phi_2(t)$

$\phi_1(t) = Q_{14}(t) Ⓢ \phi_4(t) + Q_{15}(t)$

$\phi_2(t) = Q_{24}(t) Ⓢ \phi_4(t) + Q_{27}(t)$

$\phi_4(t) = Q_{43}(t) Ⓢ \phi_3(t)$

$\phi_3(t) = Q_{30}(t) Ⓢ \phi_0(t) + Q_{36}(t) + Q_{38}(t)$ (4)

Taking LST of above relations (4) and solving for $\Phi_0^{**}(s)$, we have

$R^*(s) = \frac{1-\phi_0^{**}(s)}{s}$ (5)

The reliability of the system model can be obtained by taking Inverse Laplace transform of (5).

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

MTSF = $\lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{N}{D}$, where (6)

$N = \mu_0 + p_{01}\,\mu_1 + p_{02}\,\mu_2 + (\mu_3 + \mu_4)(p_{01}\,p_{14} + p_{02}\,p_{24})$

and

$D = 1 - p_{01}p_{14}\,p_{30} - p_{02}p_{24}\,p_{30}$ (7)

5. Steady State Availability

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:

$A_0(t) = M_0(t) + q_{01}(t) © A_1(t) + q_{02}(t) © A_2(t)$

$A_1(t) = M_1(t) + q_{14}(t) © A_4(t) + q_{13.5}(t) © A_3(t)$

$A_2(t) = M_2(t) + q_{24}(t) © A_4(t) + q_{23.7}(t) © A_3(t)$
$A_4(t) = M_4(t) + q_{43}(t) © A_3(t)$
$A_3(t) = M_3(t) + q_{30}(t) © A_0(t) + q_{31.8}(t) © A_1(t) + q_{32.6}(t) © A_2(t)$ (8)

where,
$M_0(t) = e^{-(\alpha_0+\lambda)t}$, $M_1(t) = e^{-\lambda_1 t}\overline{F(t)}$, $M_2(t) = e^{-\lambda_1 t}\overline{G(t)}$,
$M_3(t) = e^{-(\alpha_0+\lambda)t}\overline{R(t)}$
$M_4(t) = e^{-\lambda_1 t}$ (9)

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

$A_0(\infty) = \lim_{s\to 0} sA_0^*(s) = \frac{N_1}{D_1}$, where (10)

$N_1 = p_{30}\mu_0 + \mu_1(p_{01}(1 - p_{32.6}) + p_{02}p_{31.8}) + \mu_2(p_{02}(1 - p_{31.8}) + p_{01}p_{32.6})$
$+\mu_3 + \mu_4(p_{01}p_{14}(1 - p_{32.6}p_{23.7}) + p_{02}p_{24}(1 - p_{31.8}p_{13.5}) + p_{02}p_{14}p_{23.7}p_{31.8} +$
$p_{01}p_{32.6}p_{13.5}p_{24})$ (11)

and

$D_1 = p_{30}\mu_0 + \mu_1'(p_{01}p_{30} + p_{31.8}) + \mu_2'(p_{02}p_{30} + p_{32.6}) + \mu_3' +$
$\mu_4(p_{24}p_{32.6} + p_{31.8}p_{14} + p_{30}(p_{01}p_{14} + p_{02}p_{24}))$ (12)

6. Busy Period Analysis for Server

6.1 Due to Repair

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

$B_0^R(t)=q_{01}(t)© B_1^R(t)+q_{02}(t)© B_2^R(t)$
$B_1^R(t)=q_{14}(t)© B_4^R(t)+q_{13.5}(t)© B_3^R(t)$
$B_2^R(t)= W_2(t)+q_{24}(t)© B_4^R(t)+q_{23.7}(t)© B_3^R(t)$
$B_4^R(t)=q_{43}(t)© B_3^R(t)$
$B_3^R(t)= q_{30}(t)© B_0^R(t)+q_{31.8}(t)© B_1^R(t) +q_{32.6}(t)© B_2^R(t)$ (13)

where

$W_2(t) = e^{-\lambda_1 t}\overline{G(t)} + (\lambda_1 e^{-\lambda_1 t}©1)\overline{G(t)}$ (14)

Taking LT of above relations (13) and solving for ${B_0}^{R^*}(s)$.The time for which server is busy due to repair is given by

${B_0}^{R^*}(\infty) = \lim_{s\to 0} s{B_0}^{R^*}(s) = \frac{N_2}{D_1}$, where (15)

$N_2 = W_2^*(0)(p_{01}p_{32.6} + p_{02}(1 - p_{31.8}))$ (16)

and, D_1 is already mentioned.

6.2 Due to Replacement

Let $B_i^{Rp}(t)$ be the probability that the server is busy in replacement the unit at an instant ‘t’ given that the system entered regenerative state Si at t=0.The recursive relations for $B_i^{Rp}(t)$are as follows:

$B_0^{Rp}(t) = q_{01}(t)©B_1^{Rp}(t) + q_{02}(t)©B_2^{Rp}(t)$
$B_1^{Rp}(t) = q_{14}(t)©B_4^{Rp}(t) + q_{13.5}(t)©B_3^{Rp}(t)$
$B_2^{Rp}(t) = q_{24}(t)©B_4^{Rp}(t) + q_{23.7}(t)©B_3^{Rp}(t)$

$B_4^{Rp}(t) = q_{43}(t)©B_3^{Rp}(t)$
$B_3^{Rp}(t) = W_3(t) + q_{30}(t)©B_0^{Rp}(t) + q_{31.8}(t)©B_1^{Rp}(t) + q_{32.6}(t)©B_2^{Rp}(t)$ (17)
where,
$W_3(t) = e^{-(\alpha_0+\lambda)t}\overline{R(t)} + (\alpha_0 e^{-(\alpha_0+\lambda)t}©1)\overline{R(t)} + (\lambda e^{-(\alpha_0+\lambda)t}©1)\overline{R(t)}$ (18)

Taking LT of above relations (17) and solving for $B_0^{Rp^*}(s)$.The time for which server is busy due to replacement is given by
$B_0^{Rp}(\infty) = \lim_{s\to 0} s\, B_0^{Rp^*}(s) = \frac{N_3}{D_1}$ (19)
where
$N_3 = W_3^*(0)$ (20)
and D_1 is already mentioned.

6.3 Due to Preventive Maintenance

Let $B_i^P(t)$ be the probability that the server is busy in preventive maintenance the unit at an instant 't' given that the system entered regenerative state Si at t=0.The recursive relations for $B_i^P(t)$ are as follows:
$B_0^P(t) = q_{01}(t)©B_1^P(t) + q_{02}(t)©B_2^P(t)$
$B_1^P(t) = W_1(t) + q_{14}(t)©B_4^P(t) + q_{13.5}(t)©B_3^P(t)$
$B_2^P(t) = q_{24}(t)©B_4^P(t) + q_{23.7}(t)©B_3^P(t)$
$B_4^P(t) = q_{43}(t)©B_3^P(t)$
$B_3^P(t) = q_{30}(t)©B_0^P(t) + q_{31.8}(t)©B_1^P(t) + q_{32.6}(t)©B_2^P(t)$ (21)
where,
$W_1(t) = e^{-\lambda_1 t}\overline{F(t)} + (\lambda_1 e^{-\lambda_1 t}©1)\overline{F(t)}$ (22)

Taking LT of above relations (21) and solving for $B_0^{P^*}(s)$.The time for which server is busy due to preventive maintenance is given by
$B_0^P(\infty) = \lim_{s\to 0} s\, B_0^{P^*}(s) = \frac{N_4}{D_1}$ (23)
where
$N_4 = W_1^*(0)(p_{01}(1-p_{32.6}) + p_{02}p_{31.8})$ (24)
and D_1 is already mentioned.

7. Expected Number of Repairs

Let $R_i(t)$ be the expected number of repairs by the server in (0, t] given that the system entered the regenerative state Si at t = 0. The recursive relations for $R_i(t)$ are given as:
$R_0(t) = Q_{01}(t)ⓈR_1(t) + Q_{02}(t)ⓈR_2(t)$
$R_1(t) = Q_{14}(t)ⓈR_4(t) + Q_{13.5}(t)ⓈR_3(t)$
$R_2(t) = Q_{24}(t)Ⓢ(1 + R_4(t)) + Q_{23.7}(t)Ⓢ(1 + R_3(t))$
$R_4(t) = Q_{43}(t)ⓈR_3(t)$
$R_3(t) = Q_{30}(t)ⓈR_0(t) + Q_{32.6}(t)ⓈR_2(t) + Q_{31.8}(t)ⓈR_1(t)$ (25)

Taking LST of above relations (25) and solving for $R_0^{**}(s)$.The expected number of repairs per unit time by the server is given by
$R_0(\infty) = \lim_{s\to 0} s\, R_0^{**}(s) = \frac{N_5}{D_1}$ (26)

where
$N_5 = p_{01}p_{32.6} + p_{02}(1 - p_{31.8})$ (27)
and D_1 is already mentioned.

8. Expected Number of Replacements

Let $R_{p_i}(t)$be the expected number of replacements by the server in (0, t] given that the system entered the regenerative state Si at t = 0. The recursive relations for $R_{p_i}(t)$ are given as:

$$R_{p_0}(t) = Q_{01}(t)Ⓢ R_{p_1}(t) + Q_{02}(t)Ⓢ R_{p_2}(t)$$
$$R_{p_1}(t) = Q_{14}(t)Ⓢ R_{p_4}(t) + Q_{13.5}(t)Ⓢ R_{p_3}(t)$$
$$R_{p_2}(t) = Q_{24}(t)Ⓢ R_{p_4}(t) + Q_{23.7}(t)Ⓢ R_{p_3}(t)$$
$$R_{p_4}(t) = Q_{43}(t)Ⓢ R_{p_3}(t)$$
$$R_{p_3}(t) = Q_{30}(t)Ⓢ(1 + R_{p_0}(t)) + Q_{32.6}(t)Ⓢ\left(1 + R_{p_2}(t)\right) + Q_{31.8}(t)Ⓢ(1 + R_{p_1}(t)) \quad (28)$$

Taking LST of above relations (28) and solving for$R_{p_0}^{**}(s)$. The expected number of replacements per unit time by the server is given by
$R_{p_0}(\infty) = \lim_{s\to 0} sR_{p_0}^{**}(s) = \frac{N_6}{D_1}$ (29)
where
$N_6 = 1$ and D_1 is already mentioned (30)

9. Expected Number of Preventive Maintenances

Let P_i(t)be the expected number of preventive maintenances by the server in (0, t] given that the system entered the regenerative state S_i at t = 0. The recursive relations for P_i(t)are given as:

$$\mathrm{P}_0(\mathrm{t}) = \mathrm{Q}_{01}(\mathrm{t})Ⓢ\mathrm{P}_1(\mathrm{t}) + \mathrm{Q}_{02}(\mathrm{t})Ⓢ\mathrm{P}_2(\mathrm{t})$$
$$\mathrm{P}_1(\mathrm{t}) = \mathrm{Q}_{14}(\mathrm{t})Ⓢ(1 + \mathrm{P}_4(\mathrm{t})) + \mathrm{Q}_{13.5}(\mathrm{t})Ⓢ(1 + \mathrm{P}_3(\mathrm{t}))$$
$$\mathrm{P}_2(\mathrm{t}) = \mathrm{Q}_{24}(\mathrm{t})Ⓢ\mathrm{P}_4(\mathrm{t}) + \mathrm{Q}_{23.7}(\mathrm{t})Ⓢ\mathrm{P}_3(\mathrm{t})$$
$$\mathrm{P}_4(\mathrm{t}) = \mathrm{Q}_{43}(\mathrm{t})Ⓢ\mathrm{P}_3(\mathrm{t})$$
$$\mathrm{P}_3(\mathrm{t}) = \mathrm{Q}_{30}(\mathrm{t})Ⓢ\mathrm{P}_0(\mathrm{t}) + \mathrm{Q}_{32.6}(\mathrm{t})Ⓢ\mathrm{P}_2(\mathrm{t}) + \mathrm{Q}_{31.8}(\mathrm{t})Ⓢ\mathrm{P}_1(\mathrm{t}) \quad (31)$$

Taking LST of above relations (31) and solving for P_0^{**}(s).The expected number of preventive maintenances per unit time by the server is given by
$P_0(\infty) = \lim_{s\to 0} s\, P_0^{**}(s) = \frac{N_7}{D_1}$ (32)
where
$N_7 = p_{01}(1 - p_{32.6}) + p_{02}p_{31.8}$ and D_1 is already mentioned (33)

10. Cost-Benefit Analysis

The profit incurred to the system model in steady state can be obtained as
P= $K_0A_0 - K_1B_0^R - K_2\mathrm{B}_0^{\mathrm{Rp}} - K_3\mathrm{B}_0^{\mathrm{P}} - K_4ER_0 - K_5ER_{P_0} - K_6EPm_0$
where
P = Profit of the system model

K_0 = Revenue per unit up-time of the system
K_1 = Cost per unit time for which server is busy due to repair
K_2 = Cost per unit time for which server is busy due to replacement
K_3 = Cost per unit time for which server is busy due to preventive maintenance
K_4 = Cost per unit time repair
K_5 = Cost per unit time replacement
K_6 = Cost per unit time preventive maintenance

11. Conclusion

The trends of some important reliability measures have been observed by giving arbitrary values to various parameters and costs. For this purpose the results for Mean Time to System failure (MTSF), availability and profit function are obtained in steady state by considering the particular case $g(t)= \theta e^{-\theta t}$, $f(t) = \beta e^{-\beta t}$ and $r(t)= \alpha e^{-\alpha t}$. The figures 2, 3 and 4 indicate respectively that MTSF, availability and profit function keep on increasing with the increase of repair rate (θ), replacement rate (α) and preventive maintenance rate (β). However, their values decline with the increase of failure rates (λ and λ_1) and the rate (α_0) by which unit undergoes for preventive maintenance. Finally, it is analyzed that a system of non-identical units can be made more reliable and profitable to use by increasing repair rate of the main unit and replacement rate of the duplicate unit. The results for MTSF, availability and profit functions are also presented numerically in Tables 1, 2 and 3 respectively.

12. Numerical Presentation of Reliability Measures

Repair Rate (θ)	λ=0.2,λ_1=0.25,α=5, α_0=0.05,β=1.5	λ_1=0.15	α=7	α_0=0.07	β=2.5
2.1	52.40334	93.69776	56.31042	48.84935	55.96871
2.2	53.54395	95.48483	57.65435	49.79617	57.27108
2.3	54.63979	97.18702	58.95079	50.70169	58.52596
2.4	55.69344	98.81021	60.20223	51.56855	59.73588
2.5	56.70730	100.35979	61.41097	52.39917	60.90323
2.6	57.68357	101.84065	62.57915	53.19577	62.03020
2.7	58.62432	103.25727	63.70879	53.96041	63.11887
2.8	59.53144	104.61373	64.80175	54.69497	64.17114
2.9	60.40670	105.91379	65.85980	55.40119	65.18882
3.0	61.25176	107.16090	66.88459	56.08069	66.17358

Table 1: MTSF Vs Repair Rate (θ)

Repair Rate (θ)	λ=0.2,λ_1=0.25,α=5, α_0=0.05,β=1.5	λ_1=0.15	α=7	α_0=0.07	β=2.5
2.1	0.99144	0.99561	0.99200	0.99068	0.99289
2.2	0.99186	0.99581	0.99242	0.99109	0.99331
2.3	0.99223	0.99599	0.99279	0.99144	0.99368
2.4	0.99255	0.99615	0.99312	0.99175	0.99401
2.5	0.99284	0.99629	0.99341	0.99203	0.99430
2.6	0.99310	0.99641	0.99367	0.99228	0.99456
2.7	0.99333	0.99652	0.99390	0.99250	0.99479
2.8	0.99354	0.99662	0.99411	0.99270	0.99500
2.9	0.99373	0.99671	0.99430	0.99288	0.99519
3.0	0.99390	0.99679	0.99447	0.99305	0.99536

Table 2: Availability Vs Repair Rate (θ)

Repair Rate (θ)	λ=0.2,λ_1=0.25,α=5, α_0=0.05,β=1.5	λ_1=0.15	α=7	α_0=0.07	β=2.5
2.1	14067.19	14328.33	14078.75	14032.45	14092.38
2.2	14075.73	14333.19	14087.30	14040.65	14100.95
2.3	14083.33	14337.53	14094.91	14047.94	14108.57
2.4	14090.13	14341.41	14101.71	14054.45	14115.38
2.5	14096.23	14344.91	14107.83	14060.31	14121.50
2.6	14101.74	14348.07	14113.34	14065.59	14127.02
2.7	14106.73	14350.94	14118.34	14070.38	14132.03
2.8	14111.27	14353.56	14122.88	14074.73	14136.58
2.9	14115.41	14355.95	14127.03	14078.71	14140.73
3	14119.20	14358.15	14130.83	14082.34	14144.53

Table 3: Profit Vs Repair Rate (θ)

13. Graphical Presentation of Reliability Measures

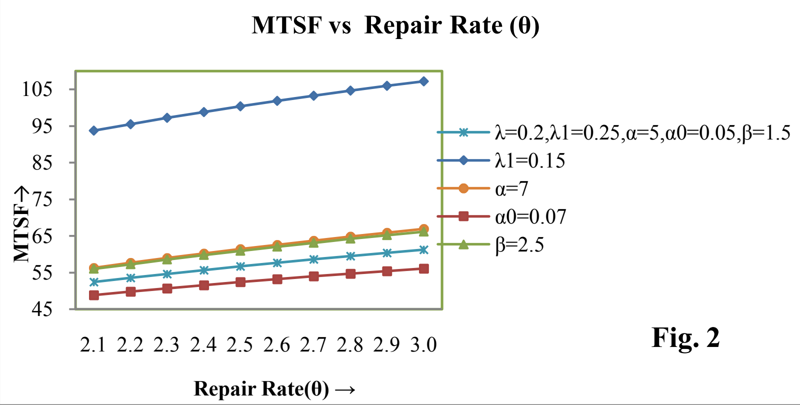

Fig. 2

Figure 2: MTSF Vs Repair Rate (θ)

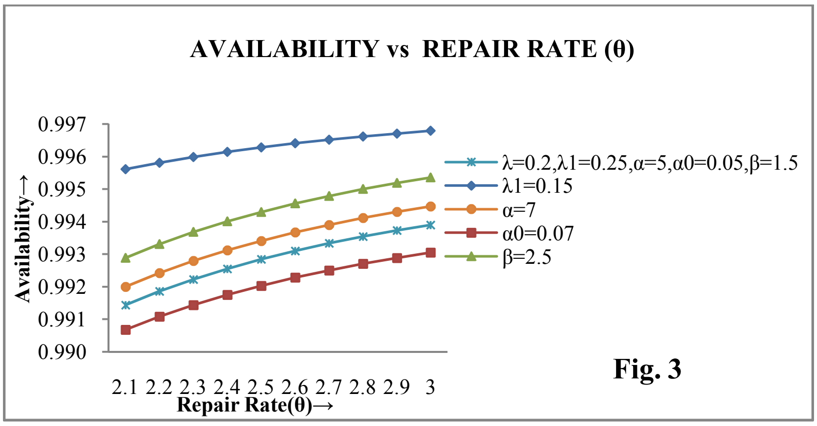

Figure 3: Availability Vs Repair Rate (θ)

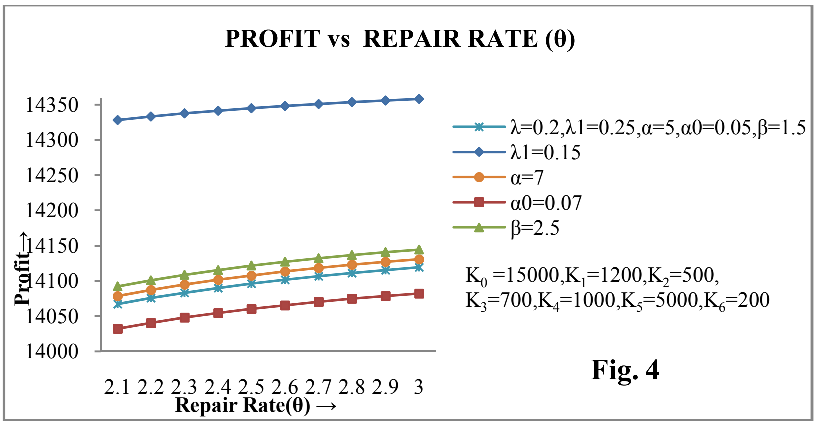

Figure 4: Profit Vs Repair Rate (θ)

Acknowledgement

The authors are grateful to the reviewers of this paper for suggesting valuable conceptual points which help in improving the worth of the work.

References

1. Jinhua Cao and Yanhong Wu (1989). Reliability of a two-unit cold standby system with replaceable repair facility, Microelectronics Reliability, 29 (2), p.145–150.

2. Dhillon. B.S. (1992). Reliability and availability analysis of a system with standby and common cause failures, Microelectronics Reliability, 33(9), p.1343– 349.
3. Goel L.R., Mumtaz S.Z. and Gupta, Rakesh (1996). A two-unit duplicating standby system with correlated failure-repair/replacement times, Microelectronics Reliability , 36(4), p.517-523.
4. Malik, S.C., Savita Deswal and Sureria, J.K. (2013). Stochastic analysis of a system of non-identical units with no repair activity in abnormal weather. International Journal of Agricultural and Statistical Sciences, 9(Supplement 1), p.193-201.
5. Kumar, Jitender, Kadyan, M. S. and Malik, S. C. (2012). Cost analysis of a two-unit cold standby system subject to degradation, inspection and priority, Eksploatacja i Niezawodnosc- Maintenance and Reliability, 14(4), p.278-283.
6. Malik, S. C. and Sudesh, K. Barak (2013). Reliability measures of a cold standby system with preventive maintenance and repair. International Journal of Reliability, Quality and Safety Engineering, 20, No. 6 (DOI: 10.1142/S0218539313500228)
7. Dhall, Anju, Malik, S. C. and Munday, Vikram (2014). A stochastic system with possible maintenance of standby unit and replacement of the failed unit subject to inspection. International Journal of Computer Applications, 97(8), p.26-30.
8. R. Rathee and Chander, S. (2014). A parallel system with priority to repair over preventive maintenance subject to maximum operation and repair times. International Journal of Statistics and Reliability Engineering, 1(1), p.57-68.