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Stochastic modeling of three non identical complex system with single service facility available in the system

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The paper deals with the the System comprising of three components A, B_1 and B_2 in which B_1 and B_2 are in parallel configuration and in series with unit A.The system fails if either A or both units B_1 and B_2 fails. A single server takes sometime to arrive the system to carry out repair activities.The repair of the system is based on first come first serve (fcfs). The failure time distribution and time to repair of all the units is taken exponential.The arrival time of the server is assumed as general.

keywords: Stochastic analysis, mean time to system failure, waiting time, regenerative point technique, busy period analysis.

1 Introduction

A system is composed of number of units, subsystms organized to an explicit design in order to achieve the direct purpose with adequate pursuance and reliability. The types of the units, their qualities, their quantities and the way in which they are put withen the system has absolute impact on the system reliability. Malfunctioning of a unit or part leads to system breakdown in some cases and may not in others, depending upon the association among the units. The cause for failure of component or equipments may be due to the poor component design or system design, complexity of equipment.One can add reliable system by adding one or more components in parallel confugration.

In reliability theory, the redundancy approach has been adopted by many analyst to enhance the execution of the repairable system. The reliability modeling of such systems

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has been done by many researchers. Marari and Goel (1984) , Li and Cao (1995) developed reliability models for redundant systems. Osaki and Nakagawa (1971) analyzed two unit redundant system. Singh (1989) studied the two cold standby units with service facality available in the system. Lam (1997) gave the concept of maintenance model for redundant system. Bhardwaj and Singh (2014) threw light on reliability analysis of standby model with server failure. Kumar et al. (2017) analysed several reliability measures of redundant systems. However, due to flying cost, it is not always reliable for users to keep an identic component as backup in cold standby. The performance and enhancement in the reliability can be further enhanced by utalizing suitable repair facilities at proper phase of operations.

In the rapidly developing global compitition industries are trying to produce reliable models to meet the demands of the society. The complexity of designs is giving its toll day by day. The enhancement in efficiency of such systems has therefore earned significant importance in recent years. Kumar et al. (2010) and Promila et al. (2010) caried out reliability analysis of a model priority to repair over replacement policy. Further, Sureria and Malik (2013) gives the reliability measures of a model with arrival time of a server and priority to repair over any other measure. Some studies have been carried out by the researchers in which the idea of arrival time of the server, repair rate of the unit, preventive maintenance, priority to repair over preventive maintenance have been introduced while developing system reliability models. Malik and Dhanka (2010) gave the concept of server failure during repair. Analysis of a non-identical unit system with priority and preventive maintenance has been done by Devi et al. (2017). Malik, Bhardwaj and Grewal (2010) in their paper gave priority to repair facility subject to inspection. Recently, Barak, Neeraj and Barak (2018) studied analysis of two unit cold standby model working under different weather conditions. Barak, Yadav and Kumari (2018) gave the concept of reliability analysis of a two-unit model with server failure.

The objective of present article is to study the three non- identical units in mixed configuration to provide a requisite level of reliability and system pursuance which has been examined stochastically and the expressions for the various reliability measures of system effectiveness are computed using regenerative point technique under certain assumptions:

1.1 Assumptions

1. The System comprises of three components A, B_1 and B_2 in which B_1 and B_2 are in parallel configuration and in series with unit A .

2. The system fails if either A or both units B_1 and B_2 fails.

3. A single server takes sometime to arrive the system to carry out repair activities of the failed unit.

4. The repair of the system is based on first come first serve (fcfs).

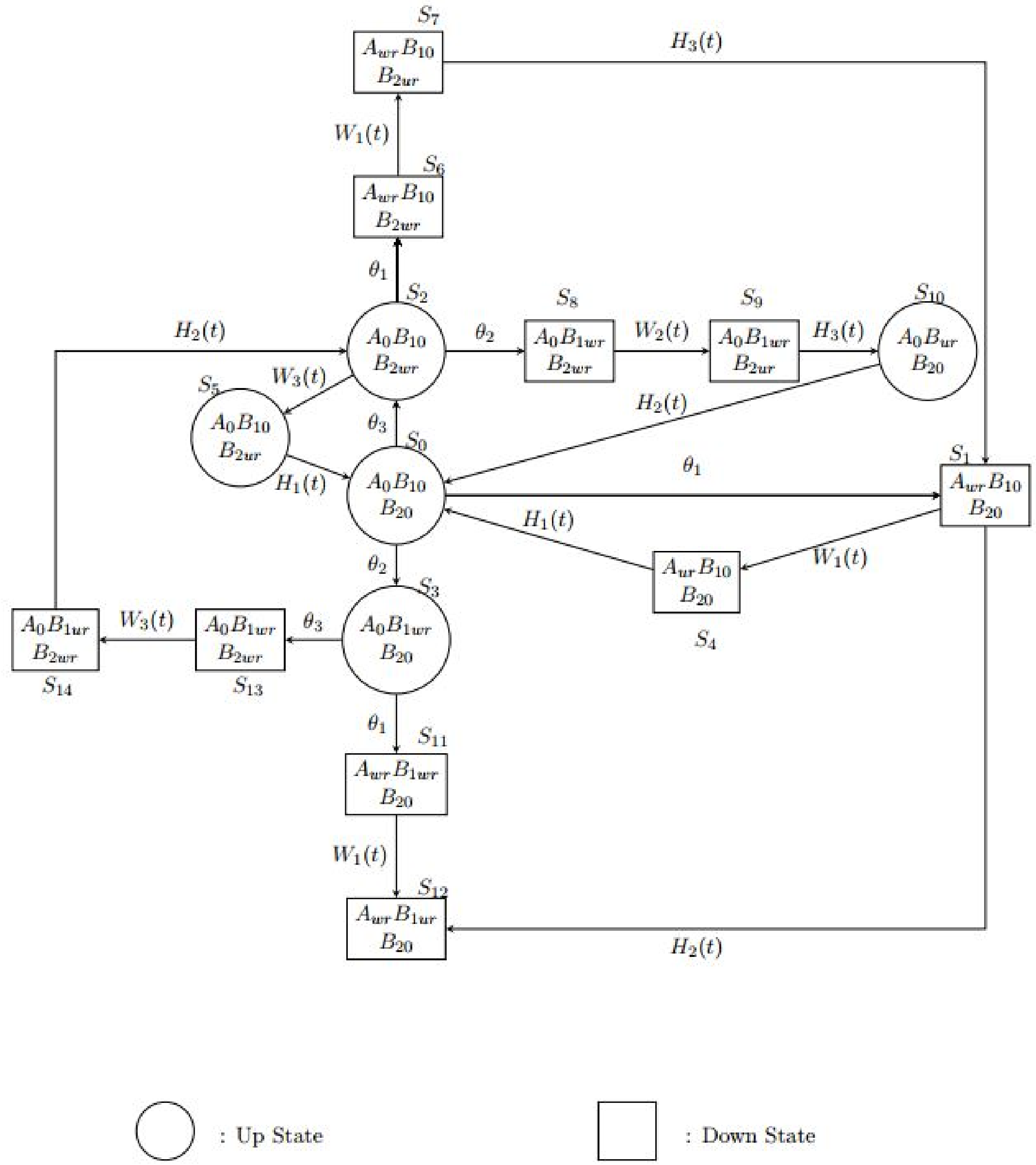
5. The failure time distribution and time to repair of all the units is taken exponential.

6. The arrival time of the server is taken as general.

1.2 Notations and Symbols

θ_1	=	failure rate of unit A
θ_2	=	failure rate of unit B_1
θ_3	=	failure rate of unit B_2
$H_1(t)$	=	cdf of repair time of the failed unit A
$H_2(t)$	=	cdf of repair time of the failed unit B_1
$H_3(t)$	=	cdf of repair time of the failed unit B_2
$W_1(t)$	=	cdf of waiting time of unit A
$W_2(t)$	=	cdf of waiting time of unit B_1
$W_3(t)$	=	cdf of waiting time of unit B_2
ψ_i	=	Mean sojourn time in state S_i
$\pi_i(t)$	=	cdf of time to system failure where starting from upto state S_0
$*$	=	Symbol for Laplace transform i.e $f^*(s) = \int_0^\infty e^{-st} f(t)dt$
$\sim$	=	Symbol for Laplace-Stieltjes transform i.e $\tilde{F}(s) = \int_0^\infty e^{-st} dF(t)dt$
A_0	=	Unit A is normal and operative.
B_{10}, B_{20}	=	Unit B_1 and Unit B_2 is normal and operative.
A_{wr}	=	Unit A is failed and waiting for repair.
B_{1wr}, B_{2wr}	=	Unit B_{1wr}, B_{2wr} are failed and waiting for repair.
A_{ur}	=	Unit A is failed and under repair.
B_{1ur}, B_{2ur}	=	Unit B_{1ur}, B_{2ur} are failed and under repair.
$M_i(t)$	=	Probability that the system sojourns in state S_i upto time t.
$p_j(t)$	=	Probability that the system is in state S_j at time t.
$Q_k(x,t)$	=	Probability that the system is in state S_k at epoch t and has sojourned in this state for duration between x and $x + dx$.
S_i	=	Total possible transition states, $i = 0, 1, 2...14$.

Transition diagram



States of the system

The possible states of the system are:

$$S_0 = [A_o B_{1o} B_{2o}]$$

$$S_1 = [A_{wr} B_{10} B_{2o}]$$

$$S_2 = [A_o B_{1o} B_{2wr}]$$

$$S_3 = [A_o B_{1wr} B_{2o}]$$

$$S_4 = [A_r B_{1o} B_{20}]$$

$$S_5 = [A_o B_{1o} B_{2r}]$$

$$S_6 = [A_{wr} B_{1o} B_{2wr}]$$

$$S_7 = [A_{wr} B_{1o} B_{2r}]$$

$$S_8 = [A_o B_{1wr} B_{2wr}]$$

$$S_9 = [A_o B_{1wr} B_{2r}]$$

$$S_{10} = [A_o B_r B_{2o}]$$

$$S_{11} = [A_{wr} B_{1wr} B_{20}]$$

$$S_{12} = [A_{wr} B_{1r} B_{2o}]$$

$$S_{13} = [A_o B_{1wr} B_{2wr}]$$

$$S_{14} = [A_o B_{1r} B_{2wr}]$$

The states $S_0, S_2, S_3, S_5, S_{10}$ are up states while $S_1, S_4, S_6, S_7, S_8, S_9, S_{11}, S_{12}, S_{13}, S_{14}$ are down states

2 Transition probabilities

2.1 Transient State

Let $Q_{ij}(t)$ represents the transition probability from state i to j. By simple calculations, the transition probabilities can be obtained as:

$$
\begin{aligned}
Q_{01}(t) &= \theta_1 \int_0^t e^{-(\theta_1+\theta_2+\theta_3)u} du \\
Q_{02}(t) &= \theta_2 \int_0^t e^{-(\theta_1+\theta_2+\theta_3)u} du \\
Q_{03}(t) &= \theta_3 \int_0^t e^{-(\theta_1+\theta_2+\theta_3)u} du \\
Q_{14}(t) &= \int_0^t W_1(u) du \\
Q_{25}(t) &= \int_0^t e^{-(\theta_1+\theta_2)u} dw_3(u) du \\
Q_{26}(t) &= \theta_1 \int_0^t e^{-(\theta_1+\theta_2)u} \bar{W}_3(u) du \\
Q_{28}(t) &= \theta_2 \int_0^t e^{-(\theta_1+\theta_2)u} \bar{W}_3(u) du \\
Q_{3,11}(t) &= \theta_1 \int_0^t e^{-(\theta_1+\theta_3)u} du \\
Q_{3,13}(t) &= \theta_1 \int_0^t e^{-(\theta_1+\theta_3)u} du \\
Q_{40}(t) &= \int_0^t H_1(u) du \\
Q_{50}(t) &= \int_0^t H_3(u) du \\
Q_{67}(t) &= \int_0^t W_1(u) du \\
Q_{71}(t) &= \int_0^t W_3(u) du \\
Q_{89}(t) &= \int_0^t W_2(u) du \\
Q_{9,10}(t) &= \int_0^t H_3(u) du \\
Q_{10,0}(t) &= \int_0^t H_2(u) du
\end{aligned}
$$

$$\begin{aligned}
Q_{11,12}(t) &= \int_0^t W_1(u)du \\
Q_{13,14}(t) &= \int_0^t W_3(u)du \\
Q_{14,2}(t) &= \int_0^t H_2(u)du
\end{aligned}$$

2.2 Steady State Transition Probabilities

In transition probabilities by taking $t \to \infty$, the required steady state probabilities are:

$$p_{01} = Q_{ij}(\infty) = \int_0^t Q_{ij}(t)$$

i.e

$$\begin{aligned}
p_{01} &= \frac{\theta_1}{\theta_1+\theta_2+\theta_3} \\
p_{02} &= \frac{\theta_2}{\theta_1+\theta_2+\theta_3} \\
p_{13} &= \frac{\theta_3}{\theta_1+\theta_2+\theta_3} \\
p_{14} &= 1 \\
p_{25} &= \tilde{W}(\theta_1+\theta_2) \\
p_{26} &= \frac{\theta_1}{\theta_1+\theta_2}[1-\tilde{W}(\theta_1+\theta_2)] \\
p_{28} &= \frac{\theta_2}{\theta_1+\theta_2}[1-\tilde{W}(\theta_1+\theta_2)] \\
p_{3,11} &= \frac{\theta_1}{\theta_1+\theta_3} \\
p_{3,13} &= \frac{\theta_3}{\theta_1+\theta_3} \\
p_{40} &= p_{50} = p_{67} = p_{71} = p_{89} = p_{9,10} = p_{10,0} = p_{11,12} = p_{12,1} = p_{13,14} = p_{14,2} = 1
\end{aligned}$$

It is easily verified that $\sum_j p_{ij} = 1$, for all possible values of i.

2.3 Mean Sojourn Times

The Mean Sojourn Time (MST) denoted by ψ_i is the expected time taken by a system in a particular state before transisting to another state. It is also called the survival state. If T_i denotes the sojourn time in state S_i then MST ψ_i in state S_i is:

$$\psi_i = E\left[T_i\right] = \int_0^\infty P(T_i > t)dt$$

Thus

$$\begin{aligned}
\psi_0 &= \frac{1}{\theta_1+\theta_2+\theta_3} \\
\psi_1 &= \int_0^\infty \bar{W}_1(t)dt \\
\psi_2 &= \int_0^\infty e^{-(\theta_1+\theta_2)t}\bar{W}_1(t)dt \\
\psi_3 &= \frac{1}{\theta_1+\theta_3} \\
\psi_4 &= \int_0^\infty \bar{H}_1(t)dt \\
\psi_5 &= \int_0^\infty \bar{H}_3(t)dt \\
\psi_6 &= \int_0^\infty \bar{W}_1(t)dt \\
\psi_7 &= \int_0^\infty \bar{W}_3(t)dt \\
\psi_8 &= \int_0^\infty W_2(t)dt \\
\psi_9 &= \int_0^\infty \bar{W}_3(t)dt \\
\psi_{10} &= \int_0^\infty \bar{H}_2(t)dt \\
\psi_{11} &= \int_0^\infty \bar{W}_1(t)dt \\
\psi_{12} &= \int_0^\infty \bar{H}_2(t)dt \\
\psi_{13} &= \int_0^\infty \bar{W}_3(t)dt \\
\psi_{14} &= \int_0^\infty \bar{H}_2(t)dt
\end{aligned}$$

3 Mean time to system failure

It is the time the system takes to reach its failed mode for the first time. We define $\pi_i(t)$ as the c.d.f. of the failure time of the system for the first time when system starts function from state S_i. We use the arguments of regenerative point process to obtain $\pi_i(t)$ for different values of i. We take the Laplace transformation and solve for $\pi_0(s)$, we get:

$$\tilde{\pi}_0(s) = \frac{N_1(s)}{D_1(s)}$$

where

$$\begin{aligned} N_1(s) &= \tilde{Q}_{01}(s) + \tilde{Q}_{02}(s)\tilde{Q}_{28}(s) + \tilde{Q}_{02}(s)\tilde{Q}_{26}(s) + \tilde{Q}_{03}(s)\tilde{Q}_{3,11}(s) + \tilde{Q}_{03}(s)\tilde{Q}_{3,13}(s) \\ D_1(s) &= (1 - \tilde{Q}_{02}(s)\tilde{Q}_{25}(s)) \end{aligned}$$

On taking $s \to 0$ and using the relation $Q_{ij}(s) \to P_{ij}$, we have

$$\tilde{\pi}_0(s) = \frac{N_1(s)}{D_1(s)} = 1$$

Thus $N_1(0) = D_1(0)$ showing that $\tilde{\pi}_0(0) = 1$. Hence $\pi_0(t)$ is a proper cdf. Therefore, MTSF when the initial state is S_0 is obtained as:

$$E(T) = \left.\frac{\tilde{\pi}_0(s)}{ds}\right|_{s=0} = \frac{D_1'(0) - N_1'(0)}{D_1(0)}$$

where,

$$\begin{aligned} D_1'(0) - N_1'(0) &= \psi_0 + \psi_2 p_{02} + \psi_3 p_{03} + \psi_5 p_{02} p_{25} \\ D_1(0) &= (1 - p_{02} p_{20} p_{50}) \end{aligned}$$

$$MTSF = \frac{\psi_0 + \psi_2 p_{02} + \psi_3 p_{03} + \psi_5 p_{02} p_{25}}{(1 - p_{02} p_{25} p_{50})}$$

4 Availability

It is the measure of system performance and can be defined as the proportion of time the system is available for its function withen specific duration.We consider $A_i(t)$ as the probability that the system is available for its function at epoch $'t'$ when it initially starts from regenerative state S_i. We use simple probablistic argument in order to obtain recurrence relations among different pointwise availibilities $A_i(t)$.We take the Laplace transformation and solve for $A_0^*(s)$, get get:

$$A_0^*(s) = \frac{N_2(s)}{D_2(s)}$$

where

$$N_2(s) = M_0^* + q_{02}^* M_2^* + q_{02}^* q_{25}^* M_5^* + q_{02}^* q_{28}^* q_{89}^* q_{9,10}^* M_{10}^* + q_{03}^* M_3^* + q_{03}^* q_{3,13}^* q_{13,14}^* q_{14,2}^* q_{28}^* q_{89}^* q_{9,10}^* M_{10}^* + q_{03}^* q_{3,13}^* q_{13,14}^* q_{14,2}^* M_2^* + q_{03}^* q_{3,13}^* q_{13,14}^* q_{14,2}^* M_5^* \quad (1)$$

$$D_2(s) = 1 - [q_{01}^* q_{14}^* q_{40}^* + q_{02}^* q_{50}^* q_{25}^* + q_{02}^* q_{26}^* q_{67}^* q_{71}^* q_{14}^* q_{40}^* + q_{02}^* q_{28}^* q_{89}^* q_{9,10}^* q_{10,0}^* + q_{03}^* q_{3,11}^* q_{11,12}^* q_{12,1}^* q_{14}^* q_{40}^* + q_{03}^* q_{3,13}^* q_{13,14}^* \{q_{14,2}^* q_{28}^* q_{89}^* q_{9,10}^* q_{10,0}^* + q_{14}^* q_{25}^* q_{50}^* + q_{26}^* q_{14,2}^* q_{67}^* q_{71}^* q_{14}^* q_{40}^*\}] \quad (2)$$

The steady state availability is obtained as:

$$A_0 = lim_{t\to\infty} A_0(t) = lim_{s\to 0} sA_0^*(S) = \frac{N_2(0)}{D_2'(0)}$$

where,

$$N_2(0) = \psi_0 + p_{02}\psi_2 + p_{02}p_{25}\psi_5 + p_{02}p_{28}\psi_{10} + p_{03}\psi_3 + p_{03}p_{3,13}\psi_2 + p_{03}p_{3,13}p_{28}\psi_{10} + p_{03}p_{3,13}\psi_5 \tag{3}$$

$$\begin{aligned} D_2'(0) = \psi_0 + \psi_0 p_{02} + \psi_3 p_{03} + \psi_1(p_{01} + p_{02}p_{26} + p_{03}(1 - p_{28}p_{3,13})) + \psi_4(p_{01} + p_{02}p_{26} + p_{03} \\ (p_{3,11} + p_{26}p_{3,13})) + \psi_5[p_{25}(p_{02} + p_{03}p_{3,13})] + (\psi_6 + \psi_7)(p_{02}p_{26} + p_{03}p_{3,13}p_{26}) + \\ (\psi_8 + \psi_9 + \psi_{10})(p_{02}p_{28} + p_{03}p_{28}p_{3,13}) \end{aligned} \tag{4}$$

5 Busy period analysis for regular repairman

It is defined as the probability that the repairperson in busy in the repairmemt of the failed component at time $'t'$ given that system entered state S_i at $t = 0$ Let $B_i(t)$ be the busy period analysis for regular repairman.Taking the Laplace transformation, using probablistic arguments and solving for $B_0^*(s)$, we get:

$$B_0^*(s) = \frac{N_3(s)}{D_3(s)}$$

Where,

$$\begin{aligned} N_3(s) = (q_{01}^* q_{14}^* + q_{02}^* q_{26}^* q_{67}^* q_{71}^* q_{14}^* + q_{3,11}^* q_{11,12}^* q_{12,1}^* q_{14}^* + q_{3,13}^* q_{13,14}^* q_{14,2}^* q_{26}^* q_{67}^* q_{71}^* q_{14}^*) Z_4^* \\ +(q_{02}^* q_{25}^* + q_{3,13}^* q_{13,14}^* q_{14,2}^* q_{25}^*) Z_5^* + q_{02}^* q_{26}^* q_{67}^* Z_6^* + (q_{02}^* q_{28}^* q_{89}^* + q_{3,13}^* q_{13,14}^* q_{14,2}^* \\ q_{28}^* q_{89}^*) Z_9^* + q_{3,13}^* q_{13,14}^* q_{14,2}^* q_{26}^* q_{67}^* Z_7^* + q_{3,13}^* q_{13,14}^* Z_{14}^* + (q_{02}^* q_{28}^* q_{89}^* q_{9,10}^* \\ + q_{3,13}^* q_{13,14}^* q_{14,2}^* q_{28}^* q_{89}^* q_{9,10}^*) Z_{10}^* \end{aligned}$$

$D_3(s)$ is same as availability analysis given in (2)
In steady state, the busy period for regular repairman is obtained as:

$$B_0 = lim_{t\to\infty} B_0(t) = lim_{s\to 0} sB_0^*(s) = \frac{N_3(0)}{D_3'(0)}$$

where,

$$\begin{aligned} N_3(0) = (p_{01} + p_{02}p_{26} + p_{3,13} + p_{3,13}p_{26})\psi_4 + (p_{02}p_{25} + p_{3,13}p_{25})\psi_5 + p_{02}p_{26}\psi_6 + p_{3,13} \\ p_{26}\psi_7 + (p_{02}p_{28} + p_{28}p_{3,13})\psi_9 + (p_{02}p_{28} + p_{3,13}p_{28})\psi_{10} + p_{3,13}\psi_{12} + p_{3,13}\psi_{14} \end{aligned}$$

and $D_3'(0) = D_2'(0)$ is same as that of availability in (4)

6 Expected number of visits by repairman

Let $V_i(t)$ be the expected number of visits by repairman during the time interval $(0, t]$ when the system initially starts from regenerative state S_i . Using probabilistic arguments, taking the Laplace transform and solving for $V_0^*(S)$, we get

$$\tilde{V_0}(s) = \frac{N_4(s)}{D_4(s)}$$

Where,

$$N_4(s) = q_{01}^* q_{14}^* + q_{02}^* q_{26}^* q_{67}^* (1 + q_{71}^* q_{14}^*) + q_{02}^* q_{28}^* q_{89}^* (1 + q_{9,10}^*) + q_{03}^* q_{3,11}^* q_{11,12}^* (1 + q_{12,11}^* q_{14}^*) + q_{03}^* q_{3,13}^* q_{13,14}^* (1 + q_{14,2}^* q_{25}^*) + q_{03}^* q_{3,13}^* q_{13,14}^* q_{14,2}^* q_{26}^* q_{67}^* (1 + q_{71}^* q_{14}^*) + q_{03}^* q_{3,13}^* q_{13,14}^* q_{28}^* q_{89}^* (1 + q_{14,2}^* q_{9,10}^*)$$

$D_4'(s)$ is same as availability analysis given in (2)
In steady state, number of visits per unit time is given by

$$V_0(0) = lim_{t\to\infty} \frac{V_0(t)}{t} = lim_{s\to 0} s B_0^*(s) = \frac{N_4(0)}{D_4'(0)}$$

where,

$$N_4(0) = 1 + p_{03} + p_{02}(p_{26} + p_{28}) + p_{03} p_{3,13}(p_{26} + p_{28})$$

and $D_4'(0) = D_2'(0)$ is same as that of availability given in (4)

7 Profit analysis

The expected profit acquired in a system model is obtained as :

$$P_1 = K_0 A_0 - K_1 B_0 - K_2 V_0$$

K_0	=	Revenue per unit up time of the system,
K_1	=	cost per unit time for which the repairman is busy,
K_2	=	Cost per unit visits by the repairman.
A_0	=	Total fraction of time for which the system is in up state.
B_0	=	Total fraction of time for which the server is busy.
V_0	=	Expected number of visits per unit time for the server.

8 Graphical study of system behaviour

In order to get a clear view of the behaviour of the system with respect to the different parameters involved, we plot a graph for MTSF, availability and profit function with respect to the failure rate θ_1, keeping the view other parameters fixed as shown in Fig. 1,2,3. Fig. 1 gives the graphical behaviour of MTSF w.r.t failure rate θ_1. It is seen that for a fixed values of parameters $\theta_2, \theta_3, \alpha_1, \alpha_2, \alpha_3, \lambda_1, \lambda_2, \lambda_3$, MTSF decreases as the failure rate θ_1 increases.Fig.2 gives the pictorial behaviour of availability v/s failure rate with other values of parameters fixed. The curve indicates that as the failure rate θ_1 increases , the availability of the system decreses. Further, Fig. 3 depicts the variation in profit w.r.t failure rate θ_1 , keeping the other values of parameters fixed.It is observed that as the failure rate θ_1 increases, the profit of the system decreases.

Table 1. Effect of θ_1 and fixed parameters $\theta_2, \theta_3, \alpha_1, \alpha_2, \alpha_3, \lambda_1, \lambda_2, \lambda_3$ on MTSF

θ_1	$\theta_2 = 0.65, \theta_3 = 0.06,$ $\alpha_1 = 0.04, \alpha_2 = 0.50$ $\alpha_3 = 0.57, \lambda_1 = 0.12$ $\lambda_2 = 0.02, \lambda_3 = 0.09$	$\theta_2 = 0.55, \theta_3 = 0.07,$ $\alpha_1 = 0.05, \alpha_2 = 0.60$ $\alpha_3 = 0.87, \lambda_1 = 0.13$ $\lambda_2 = 0.05, \lambda_3 = 0.08$	$\theta_2 = 0.88, \theta_3 = 0.05,$ $\alpha_1 = 0.09, \alpha_2 = 0.76$ $\alpha_3 = 0.44, \lambda_1 = 0.15$ $\lambda_2 = 0.09, \lambda_3 = 0.13$
0.1	3.40069	3.85387	2.74823
0.2	2.03978	2.30619	1.6894
0.3	1.6015	1.77443	1.374
0.4	1.34937	1.47205	1.18773
0.5	1.17624	1.26817	1.05557
0.6	1.04693	1.11843	0.9539291
0.7	0.945461	1.0026	0.872157
0.8	0.863147	0.909777	0.804415
0.9	0.794752	0.833437	0.74711
1.0	0.736865	0.769393	0.697858

Table 2. Effect of θ_1 and fixed parameters $\theta_2, \theta_3, \alpha_1, \alpha_2, \alpha_3, \lambda_1, \lambda_2, \lambda_3$ on Availability

θ_1	$\theta_2 = 0.65, \theta_3 = 0.06,$ $\alpha_1 = 0.04, \alpha_2 = 0.50$ $\alpha_3 = 0.57, \lambda_1 = 0.12$ $\lambda_2 = 0.02, \lambda_3 = 0.09$	$\theta_2 = 0.55, \theta_3 = 0.07,$ $\alpha_1 = 0.05, \alpha_2 = 0.60$ $\alpha_3 = 0.87, \lambda_1 = 0.13$ $\lambda_2 = 0.05, \lambda_3 = 0.08$	$\theta_2 = 0.88, \theta_3 = 0.05,$ $\alpha_1 = 0.09, \alpha_2 = 0.76$ $\alpha_3 = 0.44, \lambda_1 = 0.15$ $\lambda_2 = 0.09, \lambda_3 = 0.13$
0.1	0.492341	0.490687	0.494087
0.2	0.487825	0.465621	0.468985
0.3	0.4635	0.443208	0.446199
0.4	0.44171	0.422966	0.425575
0.5	0.422049	0.404559	0.406836
0.6	0.404176	0.387731	0.38973
0.7	0.387828	0.372275	0.374044
0.8	0.3728	0.358026	0.359601
0.9	0.358926	0.344843	0.346254
1.0	0.346072	0.332607	0.333881

Table 3. Effect of θ_1 and fixed parameters $\theta_2, \theta_3, \alpha_1, \alpha_2, \alpha_3, \lambda_1, \lambda_2, \lambda_3$, K_0, K_1, K_2 on Profit

θ_1	$\theta_2 = 0.65, \theta_3 = 0.06$, $\alpha_1 = 0.04, \alpha_2 = 0.50$ $\alpha_3 = 0.57, \lambda_1 = 0.12$ $\lambda_2 = 0.87, \lambda_3 = 970$ $k_0 = 150, k_1 = 70$ $k_2 = 50$	$\theta_2 = 0.55, \theta_3 = 0.07$, $\alpha_1 = 0.05, \alpha_2 = 0.60$ $\alpha_3 = 0.87, \lambda_1 = 0.02$ $\lambda_2 = 0.77, \lambda_2 = 950$ $k_0 = 130, k_1 = 50$ $k_2 = 70$	$\theta_2 = 0.88, \theta_3 = 0.05$, $\alpha_1 = 0.09, \alpha_2 = 0.76$ $\alpha_3 = 0.44, \lambda_1 = 0.08$ $\lambda_2 = 0.67, \lambda_3 = 920$ $k_0 = 50, k_1 = 150$ $k_2 = 80$
0.1	886.242	622.373	391.297
0.2	856.333	607.091	380.086
0.3	817.995	580.496	361.986
0.4	781.075	553.843	343.972
0.5	714.987	528.701	327.006
0.6	714.987	505.3	311.217
0.7	685.639	483.577	296.558
0.8	658.454	463.399	282.936
0.9	633.211	444.625	270.257
1.0	609.713	427.122	258.43

Fig.1. Behaviour of MTSF w.r.t θ_1 for different values of $\theta_2,\theta_3,\alpha_1,\alpha_2,\alpha_3,\lambda_1,\lambda_2,\lambda_3$

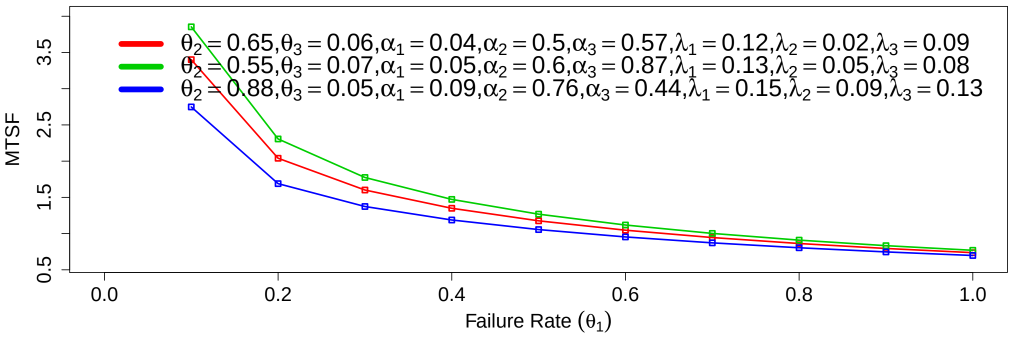


Fig.2. Behaviour Of Availibility w.r.t θ_1 for different values $\theta_2,\theta_3,\alpha_1,\alpha_2,\alpha_3,\lambda_1,\lambda_2,\lambda_3$

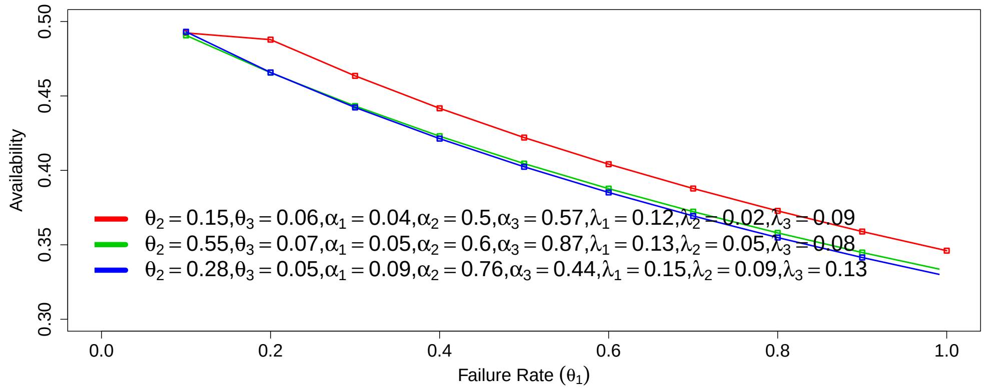
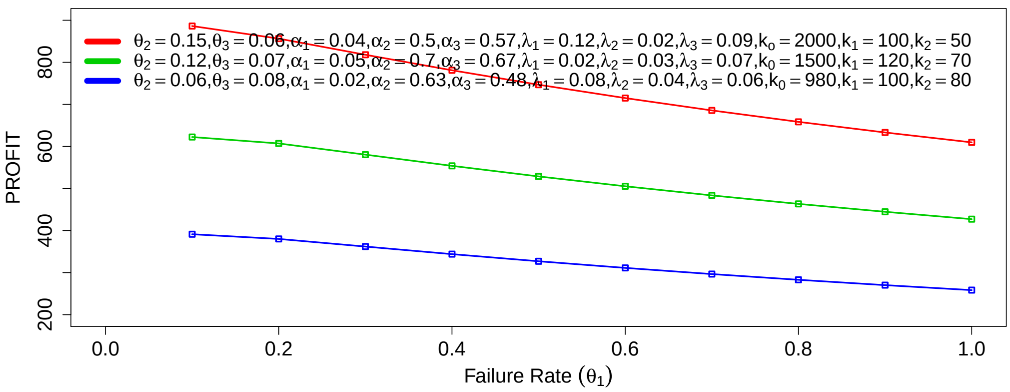


Fig.3. Behaviour of Profit w.r.t θ_1 for different values $\theta_2,\theta_3,\alpha_1,\alpha_2,\alpha_3,\lambda_1,\lambda_2,\lambda_3,k_0,k_1,k_2$



9 Conclusion

The graphs for the MTSF, availability and profit function has been drawn with respect to the failure rate, giving the arbitrary values to the other parameters and costs as shown in Fig. 1,2,3.The study winds up by the conclusion that the system can be made more productive, benificial and available by decreasing the repair rate of the component in failed mode and using the proper priority in repair disciplines, which inturn will increase the efficiency of the system.

References

Barak, M.S., Neeraj, Barak, K.S. (2018). Profit analysis of a two-unit cold standby system model operating under different weather conditions. *Life Cycle Reliability and Safety Engineering, https://doi.org/10.1007/s41872-018-0048-6.*

Barak, M.S., Yadav, D., and Kumari, S. (2018). Stochastic analysis of a two-unit system with standby and server failure subject to inspection. *Life Cycle Reliability and Safety Engineering*,7(23).

Bhardwaj, R.K., and Singh, R. (2014). Semi markov approach for asymptotic performance analysis of a standby system with server failure. *International Journal of Computer Applications*, 98(3), 9-14.

Devi, K., Kumar, A., and Saini, M. (2017). Performance analysis of a nonidentical unit system with priority and Weibull repair and failure laws. *International Journal of Computer Applications*, 177(7), 8-13.

Kumar, I., Kumar A., Saini, M., and Devi, K. (2017). Probabilistic analysis of performance measures of redundant systems under Weibull failure and repair laws. *Computing and network sustainability*, 37 (3), 247-257.

Kumar, J., Kadyan, M.S., and Malik, S.C. (2010).Cost-analysis of a system under priority to repair and degredation. *International journal of Statistics and systems*, 5(1), 1-10.

Lam, Y.F. (1997).A maintenance model for two unit redundant system. *Microelectronn Reliability*, 37(3), 497-504.

Li, W., and Cao, J. (1995). Stochastic scheduling on a repairable manufacturing system. *International Conference on Intelligent Manufacturing.* doi:10.1117/12.217486.

Malik, S.C., and Dhankar. (2010). Probabilistic Analysis of a system with server failure during repair. *Journal of reliability and statistics studies*, 3(2), 1-10.

Malik, S.C., Bhardwaj, R.K., and Grewal, A.S. (2010). Probabilistic analysis of a system of two non-identical parallel units with priority to repair subject to inspection. *Journal of Reliability and Statistical Studies*,3(1), 1-6.

Murari, K., and Goyal, V. (1984). Comparison of two-unit cold standby reliability models with three types of repair facilities. *Microelectron Reliability*, 24(1), 35-49.

Osaki, S., and Nakagawa, T. (1971). On a two unit standby redundant system with standby failure. *Operations Research*, 19(2), 510-523.

Promila, Malik, S.C., Kadyan, M.S. (2010). Analysis of an operating system with inspection to degradation and different weather conditions. *International journal of engineering science and technology (IJEST)*, 2(11), 6779-6786.

Singh, S.K., (1989). Profit evaluation of a two unit cold standby system with random appearance and disappearance time of service facility. *Microelectron Reliability*, 29, 705-709.

Sureria, J.K., and Malik, S.C. (2013). Reliability measures of a computer system with arrival time of the server and priority to H/W repair over S/W repair up- gradation. *International journal of computer application*, 65(13), 44-48.