COST-EFFECTIVENESS ANALYSIS OF A COMPLEX SYSTEM WITH DIVERSE REPAIR POLICIES UNDER NORMAL WEATHER CONDITIONS

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Abstract
The advantages of a two distinct units' system are explored using the regeneration point approach and the semi-Markov process in this research. There is a single server that comes to the system as soon as it is needed and stays with it until both units are operating. When the primary unit (Unit A) fails, it is given priority for repair over the non-identical unit (Unit B).
After repair, Unit A goes through an activation procedure, but Unit B does not require any form of activation. When unit B fails, the server inspects it to see if it needs minor or large repairs. After repairs, both devices are as good as new. Both units' failure times, unit A's repair time, and unit B's inspection time are exponentially distributed. Whereas activation time of unit A, and repair times of unit B follow the general distribution. Outcomes of the system model are exhibited graphically for constant values.

Keywords: Reliability, Advantage, Semi-Markov, Activation, Inspection, Minor/Major Repair

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1. Introduction

In the present scenario, the cost-effectiveness of a system plays a key role. Demand for the system remains high if it is more profitable in its class. To increase the profit, many researchers analyzed the reliability of numerous systems under several assumptions. Such as, Goel et. al. (1985) analyzed a two-unit cold standby system under different weather conditions, Mokkadis et. al. (1989) examined a two dissimilar unit standby system with three modes and administrative delay in repair, Goel and Sharma (1989) studied a two-unit standby system stochastically considering the concept of two failure modes and slow switch, Gupta and Goel (1991) analyzed the profit of a two-unit cold standby system with abnormal weather condition, Malik et. al (2004) stochastically analyzed a non-identical units reliability models with priority and different failure modes, Kumar and Gupta (2007) conducted the cost benefit analysis of a distillery plant, Malik et. al (2008) studied an operative system stochastically with two types of inspection subject to degradation, Pawar et. al (2010 A and B) studied the reliability system with different repair policies in different weather conditions, Gupta et. al. (2010) analyzed the profit of a two duplicate unit parallel system with repair/replacement and correlated life times of the units, Pawar and Malik (2011) measured the performance of a single-unit system subject to different failure mode in normal weather condition, Pawar et. al (2013) analyzed weathering server system operations, Kumar et. al (2017) examined the reliability of a two non-identical unit system with inspection and different repairs/replacement policies, Rathee et. al. (2018) completed the modeling and analyzed a parallel unit system with priority to repair/replacement subject to maximum operation and repair times.

Under the following assumptions, we designed and assessed a two non-identical units system employing regeneration point approach and semi-Markov process.

- There are two distinct units A and B in the system. Unit A is operational at first, while unit B is in cold standby mode.
- Unit A has four modes – normal operative, complete failure, under repair, and under activation after repair.
- Unit B has four modes – normal operative, complete failure, under inspection, and under repair.
- If one of the two units is operational, the system will be operational.
- After repair unit A requires activation before starting the operation.
- A single server comes to the system as soon as it is needed and stays with it until both units are operating.
- Priority to repair and activation is given to unit A over unit B.
- The system remains partially failed when unit A is under activation and unit B is completely failed.
- When Unit B fails, it is inspected to see if it needs minor or severe repairs.
- Both units' failure times, as well as unit A's repair time and unit B's inspection time, are exponentially distributed whereas the activation time of unit A and repair times of unit B follows general distribution.

A system advantage analysis is performed for constant values of various parameters, and graphs are generated to represent the system's behaviour.

2. Notations

A_o / A_r / A_a : Unit A is in normal operation/ under repair/ activation

B_o / B_{cs} : Unit B is in normal operation/ in cold standby mode.

B_{wi} / B_{fui} : Unit B is failed and waiting for inspection/ under inspection.

B_{wr1}/ B_{r1} : Unit B is failed and waiting for minor repair/ under minor repair.

B_{Wr2}/ B_{r2} : Unit B is failed and waiting for major repair/ under major repair.

α_1 / λ_1 : Unit A / B, constant failure rate.

θ : Inspection at a constant rate.

a/ b : Probability that the failed unit B will be repaired minor/ major. (a + b = 1)

β_1 : Constant repair rate of unit A.

$G_1(\cdot)$, $G_2(\cdot)$: c. d. f. of time to minor / major repair of unit A.

H $(\cdot)$: c. d. f. of time to activation of unit A.

$q_{i,j}$: The likelihood that the system will transition from state S_i to state S_j at or before time 't'.

ψ_i : The estimated time for which the system stays in state S_i before migrating to any other state is described as the mean sojourn time in state S_i. If T_i is the time spent in state S_i, then the mean time spent in state S_i equals is $\psi_i = \int P(T_i > t)dt$

z_i : The likelihood that the system will remain in state S_i until time t.

$m_{i,j}$: The average time spent by the system in state S_i when the system is about to enter a regenerative state S_j i.e. $m_{i,j} = \int t\, q_{i,j}(t)\, dt$

* : Symbol of Laplace Stieltjes Transformation (LST)/Laplace Transformation (LT).

©/ (s)/'(desh) : Symbols for Laplace Convolution / Stieltjes Convolution /derivative of the function.

Figure 1 depicts the model's probable transition between states as well as the transition rate.

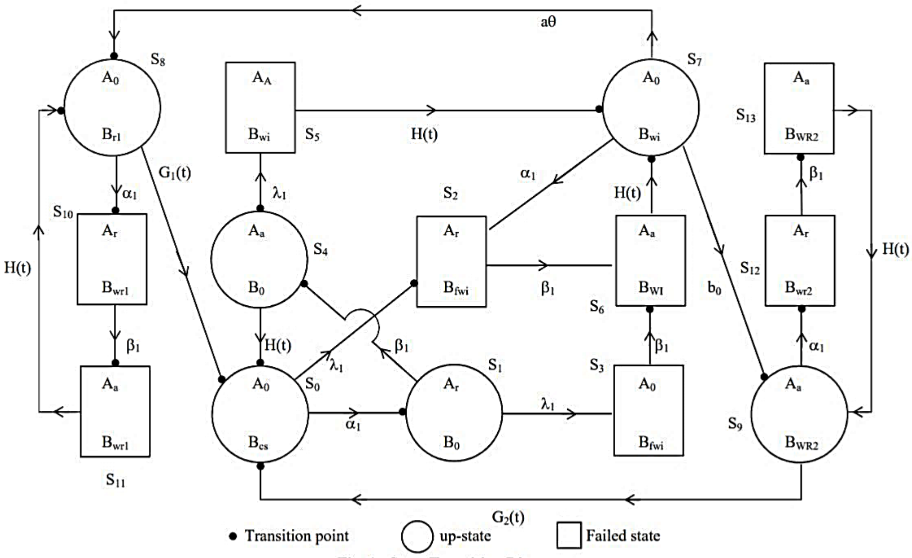


Fig. 1 : State Transition Diagram

3. Probabilities of Transition and Mean Sojourn Time:

The probability of a steady-state transition are calculated as follows:

$$p_{i,j} = \lim_{t\to\infty} q_{i,j}(t); \qquad p_{i,j}^{(k)} = \lim_{t\to\infty} q_{i,j}^{(k)}(t)$$

Therefore,

$$p_{0,1} = \frac{\alpha_1}{\alpha_1+\lambda_1}; \quad p_{0,2} = \frac{\lambda_1}{\lambda_1+\alpha_1}; \quad p_{1,4} = \frac{\beta_1}{\beta_1+\lambda_1}; \quad p_{1,6}^{(3)} = 1-\frac{\beta_1}{\lambda_1+\beta_1}$$

$$p_{2,6} = 1; \quad p_{4,0} = \tilde{H}(\lambda_1); \quad p_{4,7}^{(5)} = 1-\tilde{H}(\lambda_1); \quad p_{6,7} = 1$$

$$p_{7,2} = \frac{\alpha_1}{\alpha_1+\theta}; \quad p_{7,8} = \frac{a\theta}{\alpha_1+\theta}; \quad p_{7,9} = \frac{b\theta}{\alpha_1+\theta}; \quad p_{8,0} = \tilde{G}_1(\alpha_1)$$

$$p_{8,10} = 1-\tilde{G}_1(\alpha_1); \quad p_{9,0} = \tilde{G}_2(\alpha_1); \quad p_{9,12} = 1-\tilde{G}_2(\alpha_1); \quad p_{10,11} = 1$$

$$p_{11,18} = 1; \quad p_{12,13} = 1; \quad p_{13,9} = 1.$$

Thus, it can be verified that:

$$p_{0,1}+p_{0,2} = p_{1,4}+p_{1,6}^{(3)} = p_{2,6} = p_{4,0}+p_{4,7}^{(5)} = p_{6,7} = p_{7,2}+p_{7,8}+p_{7,9} = 1$$

$$p_{8,0}+p_{8,10} = p_{9,0}+p_{9,12} = p_{10,11} = p_{11,18} = p_{12,13} = p_{13,9} = 1$$

4. Mean Sojourn Time (ψ_i) in the state S_i are:

$$\psi_0 = \frac{1}{\lambda_1+\alpha_1}; \quad \psi_1 = \frac{1}{\lambda_1+\beta_1}; \quad \psi_2 = \frac{1}{\beta_1}; \quad \psi_4 = \int e^{-\lambda_1 u}\,\bar{H}(u)\,du$$

$$\psi_6 = \int \bar{H}(u)\,du; \quad \psi_7 = \frac{1}{\theta+\alpha_1}; \quad \psi_8 = \int e^{-\alpha_1 u}\,\bar{G}_1(u)\,du; \quad \psi_9 = \int e^{-\alpha_1 u}\,\bar{G}_2(u)\,du$$

$$\psi_{10} = \int e^{-\beta_1 u}\,du = \frac{1}{\beta_1};\quad \psi_{11} = \int \bar{H}(u)\,du;\qquad \psi_{12} = \frac{1}{\beta_1};\qquad \psi_{13} = \int \bar{H}(u)\,du.$$

5. Reliability and Mean Time to System Failure (MTSF):

To measure the system's dependability $R_i(t)$ when it first starts from the state $S_i \in E$, we suppose the failed state $S_2, S_3, S_5, S_6, S_{10}, S_{11}, S_{12}$, and S_{13} of the system as absorbing. We may demonstrate that $R_0(t)$ is the total of the following contingencies using basic probabilistic considerations.

(i) Up to time t, the system remains in state S_0 without transitioning to any other state. The likelihood of this occurrence is $e^{-(\alpha_1+\lambda_1)t} = Z_0(t)$, say

(ii) The system initially reaches state S_1 from state S_0 during (u, u + du), $u \leq t$, and then stays up continuously for the remaining period $(t-u)$, the probability of this contingency is $\int_0^t q_{0,1}(u)du\,R_1(t-u) = q_{0,1}(t) \copyright R_1(t)$

Thus, we have

$$R_0(t) = Z_0(t) + q_{0,1}(t) \copyright R_1(t)$$

Similarly,

$$R_1(t) = Z_1(t) + q_{1,4}(t) \copyright R_4(t)$$

$$R_4(t) = Z_4(t) + q_{4,0}(t) \copyright R_0(t)$$

Taking Laplace Transform of above relations, and solving for $R_0^*(s)$, we have

$$R_0^*(s) = \frac{N_1(s)}{D_1(s)} \tag{5.1}$$

Using the inverse Laplace transformation of equation (5.1), we can determine the system's dependability when it first starts from state S_0.

The average time it takes for a system to fail (MTSF) is given by $\lim_{s\to 0} R_0^*(s)$. Thus

$$\text{MTSF} = \frac{N_1(0)}{D_1(0)} = \frac{N_1}{D_1}$$

Where, $N_1 = \psi_0 + p_{0,1}(\psi_1 + \psi_4 p_{1,4})$ and $D_1 = 1 - p_{0,1}\,p_{1,4}\,p_{4,0}$.

6. Steady-State Availability

Let $A_i(t)$ be the probability that the system is up, due to a subsystem is operative at epoch t, when it initially starts from State $S_i \in E$. We can easily obtain the following recurrence relations among $A_i(t)$:

$$A_i(t) = Z_i(t) + \sum_{i,j} q_{i,j} \copyright A_j(t) \tag{6.1}$$

where, j=1,2; 4,6 ;6 ;0,7 ;7 ;2,8,9 ;0,10 ;0,12 ;11 ;8 ;9; for i = (0; 1; 2 ;4 ;6 ;7 ;8 ;9 ;10 ;11 ;12) respectively and

$Z_i(t) = 0$ for i = (2, 6, 10, 11, 12), while

$Z_0(t) = e^{-(\lambda_1+\alpha_1)t}$; $\quad Z_1(t) = e^{-(\lambda_1+\beta_1)t}$;

$Z_2(t) = e^{-\beta t}$; $\quad Z_4(t) = e^{-\lambda_1 t}\cdot\bar{H}(t)$

$Z_6(t) = \bar{H}(t)$; $\quad Z_7(t) = e^{-(\alpha_1+\theta)t}$;

$Z_8(t) = e^{-\alpha_1 t}\bar{G}_1(t)$; $\quad Z_9(t) = e^{-\alpha_1 t}\cdot\bar{G}_2(t)$;

$Z_{10}(t) = e^{-\beta_1 t}$; $\quad Z_{11}(t) = \bar{H}(t)$;

$Z_{12}(t) = e^{-\beta_1 t}$; $\quad Z_{13}(t) = \bar{H}(t)$.

Taking Laplace Transform of relation (6.1) and solving for $A_0^*(s)$, the steady-state availability can be determined as;

$$A_0 = \lim_{t\to\infty} A_0(t) = \lim_{s\to 0} sA_0^*(s) = \lim_{s\to 0} s\frac{N_2(s)}{D_2(s)}$$

The $D_2(0) = 0$, therefore by applying the L-Hospital Rule, $A_0 = \frac{N_2(0)}{D_2'(0)} = \frac{N_2}{D_2'}$

Where,

$$\begin{aligned} N_2 = {} & (1-p_{9,12})[p_{8,10}\{-Z_0(1+p_{7,2}) - Z_1 p_{0,1}(1-p_{7,2}) - p_{0,1}Z_7(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)}) \\ & - p_{0,1}p_{1,4}Z_4 - p_{0,2}Z_7\} + Z_0 + p_{0,1}Z_1 + p_{7,2}\{-Z_0 - p_{0,1}Z_1\} + p_{0,1}p_{1,4}(Z_4 + p_{4,7}^{(5)}Z_8) \\ & + (p_{0,1}p_{1,6}^{(3)} + p_{0,2}p_{7,8})Z_8 + p_{0,2}Z_7] + (1-p_{8,10})[p_{7,9}Z_9\{(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)})p_{0,1} + p_{0,2}\}] \end{aligned}$$

$$\begin{aligned} D_2' = {} & [(1-p_{7,2})p_{8,0}p_{9,0}]\psi_0 + (p_{0,1}p_{8,0}p_{9,0}(1-p_{7,2}))]\nu_1 + [(1-p_{7,2})p_{0,1}p_{1,4}p_{8,0}p_{9,0})]\nu_2 \\ & + [p_{8,0}p_{9,0}(1-p_{0,1}p_{1,4}p_{4,0})]\psi_7 + (p_{7,8}p_{9,0}(1-p_{0,1}p_{1,4}p_{4,0})]\nu_3 + [p_{7,9}p_{8,0}(1-p_{0,1}p_{1,4}p_{4,0})]\nu_4 \end{aligned}$$

The expected-up time of the system during (0, t) due to a subsystem is given by $\mu_{up}(t) = \int_0^t A_0(u)\,du$, so that $\mu_{up}^*(s) = \int_0^t \frac{A_0^*(s)}{(s)}$

7. Busy Period Analysis

(a) When the server is busy repairing a failed unit A:

Let $B_i^r(t)$ be the likelihood that the server is engaged fixing a completely failed unit A at instant time 't', when the system first begins from state S_i. We have the following recursive relations for $B_i^r(t)$ using simple probabilistic arguments:

$$B_i^r(t) = z_i(t) + \sum_{i,j} q_{i,j}(t) \copyright B_j^r(t) \quad (7.1)$$

j=1,2; 4,6; 6 ;0,7 ;7 ;2,8,9 ;0,10 ;0,12 ;11 ;8 ;13 ;9 for i = (0, 1, 2, 4, 7, 8, 9, 10, 11, 12,13) respectively and $z_i(t) = 0$ for i = (0, 4, 6, 7, 8, 9, 11, 13) while $z_1(t), z_2(t), z_{10}(t), z_{12}(t)$ have been define already.

Taking Laplace Transformation of relations (7.1) and solving for $B_0^{r*}(s)$. The busy period of the server can be obtained as $B_0^{r*}(\infty) = \lim_{s \to 0} s B_0^{r*}(s)$

Therefore, $B_0^{r*} = N_3 / D_2'$, where

$$\begin{aligned} N_3 = {} & (1-p_{9,12})[(1-p_{8,10})\{p_{0,1}\psi_1(1-p_{7,2}) + p_{0,1}p_{7,2}(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)}) + p_{0,2}\psi_2\} \\ & + p_{0,1}\psi_{10}p_{7,8}p_{8,10}(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)}) + p_{0,2}p_{7,8}p_{8,10}\psi_{10}] + (1-p_{8,10}) \\ & [p_{0,1}\psi_{12}p_{7,9}p_{9,12}(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)}) + p_{0,2}p_{7,9}p_{9,12}\psi_{12}] \end{aligned}$$

(b) when the server is engaged with activating unit A:

Let $B_i^a(t)$ be the chance that the server is busy activating unit A at instant time 't' when the system first begins from state $S_i \in E$. We have the following recursive relations for $B_i^a(t)$ using simple probabilistic arguments:

$$B_i^a(t) = z_i(t) + \sum_{i,j} q_{i,j}(t) \copyright B_j^a(t) \quad (7.2)$$

where, j=1,2 ;4,6 ;6 ;0,7 ;7 ;2 ;8,9 ;0,10 ;0,12 ;11,8,13,9 for i = (0, 1, 2, 4, 7, 8, 9, 10, 11, 12, 13) respectively and $z_i(t) = 0$ for i = (0, 1, 2, 7, 8, 9, 10, 12) while $z_4(t), z_6(t), z_{11}(t), z_{13}(t)$ have been defined already.

Taking Laplace Transformation of relations (7.2) and solving for $B_0^{a*}(s)$. The busy period of the server can be obtained as $B_0^{a*}(\infty) = \lim_{s \to 0} s B_0^{a*}(s)$

Therefore, $B_0^{a*} = N_4 / D_2'$, where

$$\begin{aligned} N_4 = {} & (1-p_{9,12})[(1-p_{8,10})\{p_{1,4}\psi_4(p_{0,1} - p_{0,2}p_{7,2}) - p_{0,1}\psi_6(p_{1,4}p_{4,7}^{(5)}p_{7,2} + p_{1,6}^{(3)})\} \\ & p_{0,2}\psi_6 + p_{0,1}p_{8,10}(p_{1,4}p_{4,7}^{(5)}p_{7,8} + p_{1,6}^{(3)}p_{7,8}) + p_{0,2}(p_{8,10}\psi_{11} + p_{7,9}p_{9,12}\psi_{13})] \\ & + (1-p_{8,10}[p_{0,1}p_{9,12}\psi_{13}(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)}p_{7,9}) \end{aligned}$$

(c) When the server is engaged in the inspection of unit B :

Let $B_i^i(t)$ be the chance that the server is engaged inspecting unit B at instant time 't' when the system first begins from state $S_i \in E$. We have the following recursive relations for $B_i^i(t)$ using simple probabilistic arguments:

$$B_i^i(t) = z_i(t) + \sum_{i,j} q_{i,j}(t) \copyright B_j^i(t) \quad (7.3)$$

where, j = 1,2 ;4,6 ;6 ;0,7 ;7 ;2 ;8,9 ;0,10 ;0,12 ;11,8,13,9 for i = (0, 1, 2, 4, 7, 8, 9, 10, 11, 12, 13) respectively and $z_i(t) = 0$ for i = (0, 1, 2, 4, 6, 8, 9, 10, 11, 12, 13) while $z_7(t)$ has been defined already.

Taking Laplace Transformation of relations (7.3) and solving for $B_0^{i*}(s)$. The busy period of the server can be obtained as $B_0^{i*}(\infty) = \lim_{s \to 0} s B_0^{i*}(s)$

Therefore, $B_0^{i*} = N_5 / D_2'$,

where,

$$N_5 = (1-p_{9,12})(1-p_{8,10})\psi_7[p_{0,1}(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)}) + p_{0,2}]$$

(d) When server is busy in minor repair of unit B :

Let $B_i^1(t)$ be the likelihood that the server is busy doing minor repairs on unit B at instant time 't' when the system boots up from state $S_i \in E$. We may derive the following recursive relations using fundamental probabilistic arguments:

$$B_i^1(t) = z_i(t) + \sum_{i,j} q_{i,j}(t) \copyright B_j^1(t) \qquad (7.4)$$

where, j = 1,2 ;4,6 ;6 ;0,7 ;7 ;2 ;8,9 ;0,10 ;0,12 ;11,8,13,9 for i = (0, 1, 2, 4, 7, 8, 9, 10, 11, 12, 13) respectively and $z_i(t)$ = 0 for i = (0, 1, 2, 4, 6, 7, 9, 10, 11, 12, 13) while $z_8(t)$ has been defined already.

Taking Laplace Transformation of relations (7.4) and solving for $B_0^{1*}(s)$. The busy period of the server can be obtained as $B_0^{1*}(\infty) = \lim_{s \to 0} s\, B_0^{1*}(s)$

Therefore, $B_0^{1*} = N_6 / D_2'$

where,

$N_6 = (1 - p_{9,12})(P_{7,8}\varphi_8[p_{0,1}(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)}) + p_{0,2}]$

(e) When the server is occupied with repairs to unit B:

Let $B_i^2(t)$ be the likelihood that the server is busy doing major repairs on unit B at instant time 't' when the system boots up from state $S_i \in E$. We may derive the following recursive relations using fundamental probabilistic arguments for $B_i^2(t)$:

$$B_i^2(t) = z_i(t) + \sum_{i,j} q_{i,j}(t) \copyright B_j^2(t) \qquad (7.5)$$

where, j = 1,2 ;4,6 ;6 ;0,7 ;7 ;2 ;8,9 ;0,10 ;0,12 ;11,8,13,9 for i = (0, 1, 2, 4, 7, 8, 9, 10, 11, 12, 13) respectively and $z_i(t)$ = 0 for i = (0, 1, 2, 4, 6, 7, 8, 10, 11, 12, 13) while $z_9(t)$ has been defined already.

Taking Laplace Transformation of relations (7.5) and solving for $B_0^{2*}(s)$. The busy period of the server can be obtained as $B_0^{2*}(\infty) = \lim_{s \to 0} s\, B_0^{2*}(s)$

Therefore, $B_0^{2*} = N_7 / D_2'$

where,

$N_7 = (1 - p_{8,10})\varphi_9 p_{7,9}[p_{0,1}(p_{1,4}p_{4,7}^{(5)} + p_{1,6}^{(3)}) + p_{0,2}]$

During (0, t), the projected busy period of the server in the mending of a total failed unit, activation of unit A, inspection, major and minor repair of unit B is provided by

$$\mu_b^{r*}(s) = \frac{B_0^{r*}(s)}{s};\ \mu_b^{a*}(s) = \frac{B_0^{a*}(s)}{s};\ \mu_b^{i*}(s) = \frac{B_0^{i*}(s)}{s};$$
$$\mu_b^{1*}(s) = \frac{B_0^{1*}(s)}{s};\quad \mu_b^{2*}(s) = \frac{B_0^{2*}(s)}{s}$$

8. Cost benefit analysis

The system's predicted profit during (0, t) is provided by, *P(t) = Expected total revenue in (0, t) - Expected total repair cost in (0, t)*

$$= K_0\,\mu_{up}(t) - K_1\mu_b^r(t) - K_2\mu_b^a(t) - K_3\mu_b^i(t) - K_4\mu_b^1(t) - K_5\mu_b^2(t)$$

where, K_0 is the revenue per unit up time by the system, K_1, K_2, K_3, K_4 and K_5, are the amounts paid per unit of time for repair, activation, inspection, minor and major repair respectively.

The expected profit per unit time in the steady state is given by:

$$P = K_0A_0 - K_1B_0^r - K_2B_0^a - K_3B_0^i - K_4B_0^1 - K_5B_0^2$$

Where $A_0, B_1^r, B_0^a, B_0^i, B_0^1$ and B_0^2 have been already defined.

9. Particular Case:

A specific situation is examined for the model under consideration where all of the repair time distributions are also exponential, i.e.

$$G_1(t) = 1 - e^{-\mu_1 t};\ G_2(t) = 1 - e^{-\mu_2 t};\ H(t) = 1 - e^{-rt}$$

The following changes have occurred in steady-state transition probabilities and mean sojourn times:

$$p_{4,0} = \frac{r}{r+\lambda_1};\qquad p_{4,7}^{(5)} = \frac{\lambda_1}{r+\lambda_1};\qquad p_{6,7} = 1;$$

$$p_{8,0} = \frac{u_1}{\alpha_1 + u_1};\qquad p_{8,10} = \frac{\alpha_1}{\alpha_1 + u_1};\qquad p_{9,12} = \frac{\alpha_1}{\alpha_1 + \mu_2};$$

$$p_{11,8} = 1;\qquad p_{13,9} = 1;\qquad m_{4,0} = \frac{r}{(r+\lambda_1)^2};$$

$$m^{(5)}_{4,7} = \frac{1}{r} - \frac{r}{(r+\lambda_1)^2}; \quad m_{6,7} = \frac{1}{r}; \quad m_{8,0} = \frac{\mu_1}{(\mu_1+\alpha_1)^2};$$

$$m_{8,10} = \frac{\alpha_1}{(\alpha_1+\mu_1)^2}; \quad m_{9,0} = \frac{\mu_2}{(\mu_2+\alpha_1)^2}; \quad m_{9,12} = \frac{\alpha_1}{(\alpha_1+\mu_2)^2};$$

$$m_{11,8} = \frac{1}{r}; \quad m_{13,9} = \frac{1}{r}; \quad \psi_4 = = \frac{1}{\lambda_1 + r};$$

$$\psi_6 = \frac{1}{r}; \quad \psi_8 = \frac{1}{\alpha_1+\mu_1}; \quad \psi_9 = \frac{1}{\alpha_1+\mu_2};$$

$$\psi_{11} = \frac{1}{r}; \quad \psi_{13} = \frac{1}{r}.$$

10. Simulation Study and conclusion:
In this model of two distinguishable unit system is developed and its advantages are analyzed such as MTSF, steady-state availability, a busy period of repairman and profit function have computed by regenerative point technique and semi-Markov process. As a specific consideration, various parameters have been fixed as $K_0 = 25000$, $K_1 = 5000$, $K_2 = 2000$, $K_3 = 1000$, $K_4 = 1500$ and $K_5 = 7000$. The other parameters are kept fixed as $b_1 = 0.7$, $q = 0.7$, $p = 0.5$, $q = 0.5$, $m_1 = 0.75$, $m_2 = 0.72$ and $g = 0.8$.

Figure-2 shows the behaviour of MTSF with respect to constant failure rate of unit A (a_1). From the figure it can be observe that MTSF decreases as a_1 increases from 0.01 to 0.15 and l_1 (the failure rate of unit B) from 0.1 to 0.11. It is also observed that the MTSF increases if b_1 (repair unit of unit A) increases.

From figure 3, which shows the behaviour of profit w.r.t. a_1. We can observe the same pattern as in case of MTSF.

Figure 2

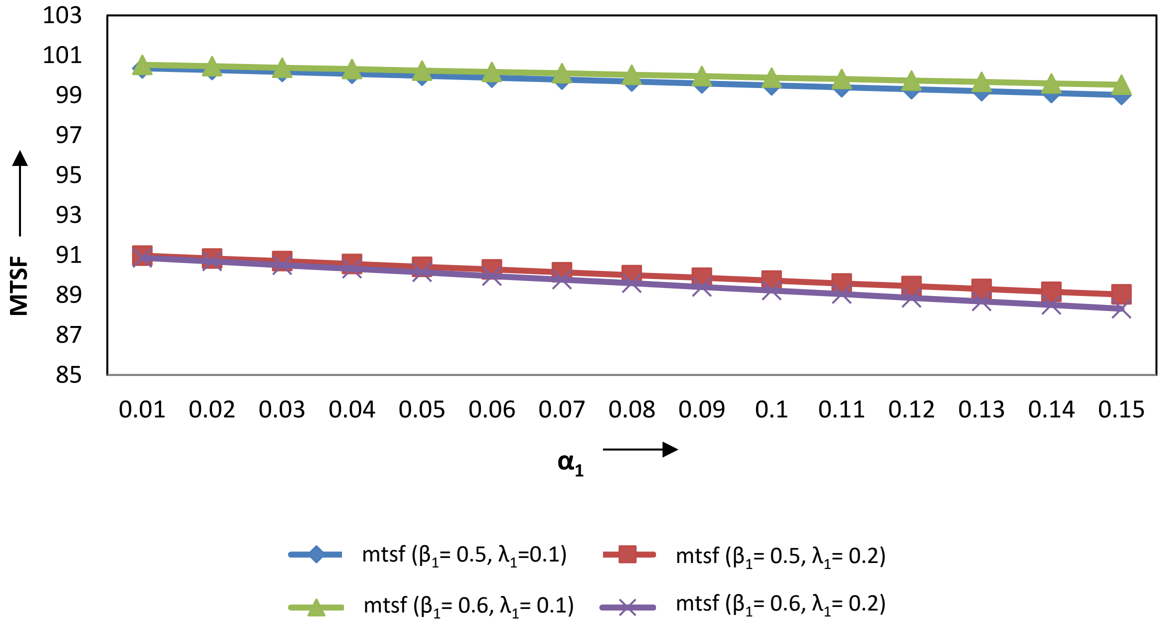
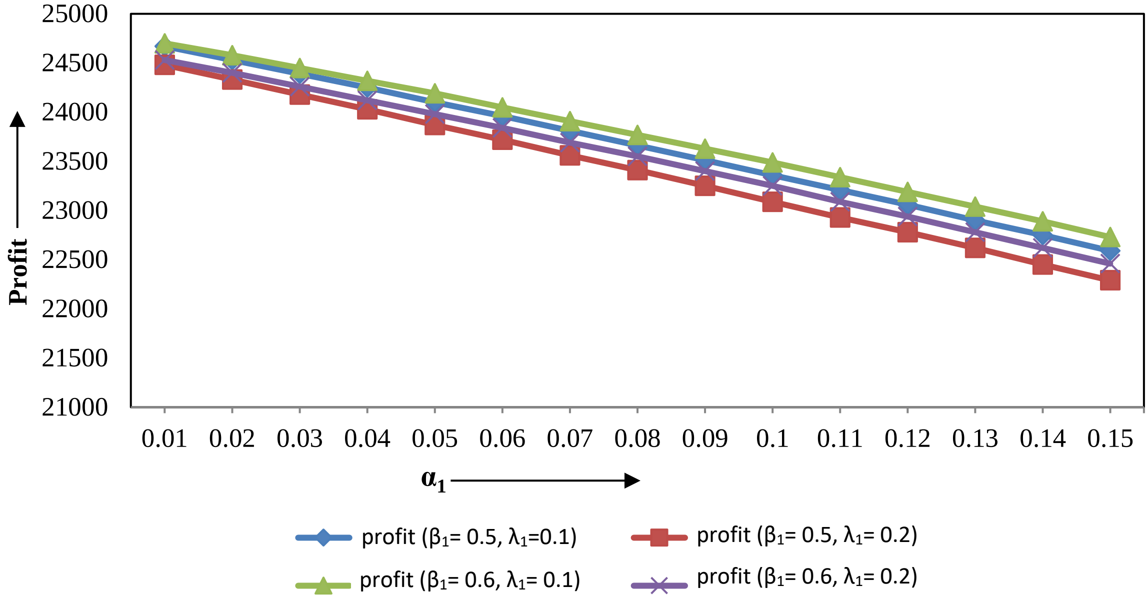


Figure 3



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