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Availability analysis of banking server with warm standby

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Abstract
Availability analysis of a local banking server with a remote standby server is analyzed for system parameters using Regenerative Point Graphical Technique (RPGT).

Keywords: Availability, Regenerative Point Graphical Technique (RPGT), System Parameters, Local Server, Remote Server

Introduction

In banking industry all the data relating to transaction history along with authorization is stored in local sever (Bank branch) and stand-by remote server. As data in baking industry is very important for customers and the management, daily data and transaction history of a branch are stored in the branch and also by the manager of the branch in the hard disc at the time of closing daily/regularly. Considering the importance of individual units in system Kumar, J. & Malik, S. C. [1] have discussed the concept of preventive maintenance for a single unit system. Liu., R. [2], Malik, S. C. [3], Nakagawa, T. and Osaki, S. [4] have discussed reliability analysis of a one unit system with un-repairable spare units and its applications. Goel, P. & Singh J. [5], Gupta, P., Singh, J. & Singh, I.P. [6], Kumar, S. & Goel, P. [7], Gupta, V. K. [8], Chaudhary, Goel & Kumar [9] Sharma & Goel [10], Ritikesh & Goel [11] and Goyal & Goel [12] have discussed behavior with perfect and imperfect switch-over of systems using various techniques. All the transaction history is stored in the remote server simultaneously because in case of failure of local server data may be retrieved from the remote server.

The failure rate of local server is much higher than that of the remote server which may be due to poor local environmental conditions such as electricity failure, earth quake, inefficient data operator and other local conditions. Remote server has better maintenance and environmental conditions as the data of all branches stored in the remote server. The management maintains better environment conditions of remote server, hence the failure rates of local server are higher than that of remote server and repair rates of local server is poor than that of remote server. On failure of local server data is retrieved from the remote server for the smooth functioning of the banking industry i.e. remote server works as warm stand to local server. Taking constant failure rates & repair rates with remote server as standby to local server a transition diagram of the system is drawn.

The system consists of local server ‘A’ and standby remote server ‘B’. There may be times when some of the banking operations may not be carried out by A or B, then the system works in reduced capacity. If the failure rate of local server ‘A’ to reduced state $\bar{A}$ is λ1, and from reduced state to failed state is λ_2 and repair rate of local server from reduced state $\bar{A}$ to A is w_2 and from failed state to reduce state $\bar{A}$ is w_1 similarly for the remote server B with failure rates λ_3, λ_4 and repair rates w_4 and w_3. It is assumed that when any of servers fails then the system is not put to use.

Fuzzy concept is used to determine failure/working state of a unit. Taking failure rates exponential, repair rates general & independent and taking into consideration various probabilities, a transition diagram of the system is developed to find Primary circuits, Secondary circuits & Tertiary circuits and Base state. Problem is solved using RPGT to determine system parameters. System behavior is discussed with the help of graphs and tables. Particular cases for arm, cold and hot standby cases are taken to study the effect of failure and repair rates on system parameters. Tables and Graphs are drawn to compare the results.

Assumptions and Notations

The following assumptions and notations are taken: -

1. A single repair facility is available.
2. The distributions of failure times and repair times are exponential and general respectively and also different.
3. Failures and repairs are statistically independent.
4. Repair is perfect and repaired system is as good as new one.
5. Nothing can fail when the system is in failed state.
6. The system is discussed for steady-state conditions.
7. Replacement of Un-repairable unit and repair facility is immediate.
8. There are separate repairmen for local and remote servers.

$\overline{cycle}$: A circuit formed through un-failed states.

m-cycle: A circuit (may be formed through regenerative or non-regenerative / failed state) whose terminals are at the regenerative state m.

$m-\overline{cycle}$: A circuit (may be formed through un-failed regenerative or non-regenerative state) whose terminals are at the regenerative m state.

$\left(i \xrightarrow{s_r} j\right)$: *r*-th directed simple path from *i*-state to j-state; r takes positive integral values for different paths from *i*-state to j-state.

$\left(\xi \xrightarrow{sff} i\right)$: A directed simple failure free path from ξ -state to i-state.

$V_{m,m}$: Probability factor of the state m reachable from the terminal state m of the m-cycle.

$V_{\overline{m,m}}$: Probability factor of the state m reachable from the terminal state m of the $m-\overline{cycle}$.

R_i (t): Reliability of the system at time t, given that the system entered the un-failed Regenerative state 'i' at t = 0.

A_i (t) : Probability of the system in up time at time 't', given that the system entered Regenerative state 'i' at t = 0.

B_i (t) : Reliability that the server is busy for doing a particulars job at time 't'; given That the system entered regenerative state 'i' at t = 0.

V_i (t) : The expected no. of server visits for doing a job in (o,t] given that the system Entered regenerative state 'i' at t = 0.

',' denote derivative

W_i (t) : Probability that the server is busy doing a particular job at time t without transiting to any other regenerative state 'i' through one or more non-regenerative states, given that the system entered the regenerative state 'i' at t = 0.

μ_i : Mean sojourn time spent in state i, before visiting any other states;

$\mu_i = \int_0^\infty R_i(t)dt$

μ_i^1 : The total un-conditional time spent before transiting to any other regenerative states, given that the system entered regenerative state 'i' at t=0.

Ni : Expected waiting time spent while doing a given job, given that the system entered regenerative state 'i' at t=0; $\eta_i = W_i^*(0)$.

ξ : Base state of the system.

f_j : Fuzziness measure of the j-state.

λ_1 : Constant failure rate of server A from full working state to reduce state.

λ_2 : Constant failure rate of local server from reduce state to complete failure.

λ_3 : Constant failure rate of remote server from full working to failed state.

λ_4 : constant failure rate of remote server from reduced state to complete failed state.

○ Regenerative State

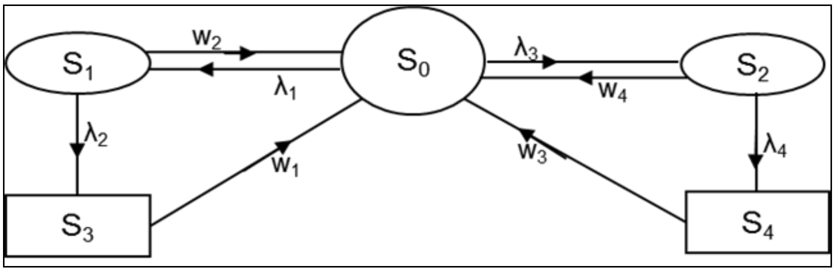
⬭ Reduced State

□ Failed State

A/$\bar{A}$/a : Unit in full capacity working / reduced state / failed state.

Similarly for the remote server B.

Taking into consideration the above assumptions and notations the Transition Diagram of the system is given in Figure 1.



S_0 = AB, $S_1 = \bar{A}$B, S_2 = A$\bar{B}$,
S_3 = aB, S_4 = Ab

Fig 1: The possible transitions rates between states along with transition states

Table 1: Various Paths from vertices

Vertex i	0	1	2	3	4
0	(0,1,0) (0,1,3,0) (0,2,0) (0,2,4,0)	(0,1)	(0,2)	(0,1,3)	(0,2,4)
1	(1,0) (1,3,0)	(1,0,1) (1,3,0,1)	(1,0,2) (1,3,0,2)	(1,3)	(1,0,2,4)
2	(2,0) (2,4,0)	(2,0,1) (2,4,,0,1)	(2,0,2) (2,4,0,2)	(2,0,1,3) (2,4,0,1,3)	(2,4)
3	(3,0)	(3,0,1)	(3,0,2)	(3,0,1,3)	(3,0,2,4)
4	(4,0)	(4,0,1)	(4,0,2)	(4,0,1,3)	(4,0,2,4)

The possible transitions rates between states along with transition states are shown in Fig 1. Primary, Secondary and Tertiary Circuits associated with the system are given in Table 2

Table 2: Primary, Secondary & Tertiary Circuits at various vertices

Vertex i	Primary Circuits (CL1)	Secondary Circuits (CL2)	Tertiary Circuits (CL3)
0	(0,1,0) (0,1,3,0) (0,2,0) (0,2,4,0)	Nil Nil Nil Nil	Nil Nil Nil Nil
1	(1,0,1) (1,3,0,1)	(0,2,0) (0,2,4,0) (0,2,0) (0,2,4,0)	Nil Nil Nil Nil
2	(2,0,2) (2,4,0,2)	(0,1,0) (0,1,3,0) (0,1,0) (0,1,3,0)	Nil Nil Nil Nil
3	(3,0,1,3)	(0,1,0) (0,2,0) (0,2,4,0)	Nil Nil Nil
4	(4,0,2,4)	(0,1,0) (0,1,3,0) (0,2,0)	Nil Nil Nil

From the table 2, we see that at working state ‘0’ there are maximum number of primary circuits, hence state ‘0’ is the base state. Primary, Secondary, Tertiary Circuits w. r. t. the Simple Paths (Base-State ‘0’)

Table 3: Transition Probability and the Mean sojourn times

Vertex j	$\left(0 \xrightarrow{S_r} j\right)$: ($P_0$)	(P_1)
0	$\left(0 \xrightarrow{S_1} 0\right)$: (0,1,0) (0,1,3,0) (0,2,0) (0,2,4,0)	- - - -
1	$\left(0 \xrightarrow{S_1} 1\right)$: (0,1)	-

2	$\left(0 \xrightarrow{S_1} 2\right)$: (0,2)	-
3	$\left(0 \xrightarrow{S_1} 3\right)$: (0,1,3)	-
4	$\left(0 \xrightarrow{S_1} 4\right)$: (0,2,4)	-

$q_{i,j}(t)$**:** Probability density function (p.d.f.) of the first passage time from a regenerative state 'i' to a regenerative state 'j' or to a failed state 'j' without visiting any other regenerative state in (0,t].

$p_{i,j}$**:** Steady state transition probability from a regenerative state 'i' to a regenerative state 'j' without visiting any other regenerative state. $p_{i,j} = q^*_{i,j}(0)$; where * denotes Laplace transformation.

Table 4: Transition Probabilities

$q_{i,j}(t)$	$P_{ij} = q^*_{i,j}(0)$
$q_{0,1} = \lambda_1 e^{-(\lambda_1+\lambda_3)t}$ $q_{0,2} = \lambda_3 e^{-(\lambda_1+\lambda_3)t}$	$p_{0,1} = \lambda_1/(\lambda_1+\lambda_3)$ $p_{0,2} = \lambda_3/(\lambda_1+\lambda_3)$
$q_{1,0} = w_2 e^{-(w_2+\lambda_2)t}$ $q_{1,3} = \lambda_2 e^{-(\lambda_2+w_2)t}$	$p_{1,0} = w_2/(w_2+\lambda_2)$ $p_{1,3} = \lambda_2/(\lambda_2+w_2)$
$q_{2,0} = w_4 e^{-(w_4+\lambda_4)t}$ $q_{2,4} = \lambda_4 e^{-(\lambda_4+w_4)t}$	$p_{2,0} = w_4/(w_4+\lambda_4)$ $p_{2,4} = \lambda_4/(\lambda_4+w_4)$
$q_{3,0} = w_1 e^{-w_1 t}$	$p_{3,0} = 1$
$q_{4,0} = w_3 e^{-w_3 t}$	$p_{4,0} = 1$

Mean Sojourn Times

$R_i(t)$: Reliability of the system at time t, given that the system in regenerative state i.

μ_i : Mean sojourn time spent in state i, before visiting any other states;

Table 5: Mean Sojourn Times

$R_i(t)$	$\mu_i = R_i^*(0)$
$R_0(t) = e^{-(\lambda_1+\lambda_3)t}$	$\mu_0 = 1/(\lambda_1+\lambda_3)$
$R_1(t) = e^{-(\lambda_2+w_2)t}$	$\mu_1 = 1/(\lambda_2+w_2)$
$R_2(t) = e^{-(\lambda_4+w_4)t}$	$\mu_2 = 1/(\lambda_4+w_4)$
$R_3(t) = e^{-w_1 t}$	$\mu_3 = 1/w_1$
$R_4(t) = e^{-w_3 t}$	$\mu_4 = 1/w_4$

Evaluation of Parameters

The Mean time to system failure and all the key parameters of the system under steady state conditions are evaluated, applying Regenerative Point Graphical Technique (RPGT) and using '0' as the base-state of the system as under:

The transition probability factors of all the reachable states from the base state 'ξ' = '0' are:

Probabilities from state '0' to different vertices are given as

$V_{0,0}$ = (0,1,0)+(0,1,3,0)+(0,2,0)+(0,2,4,0)

$= p_{0,1}p_{1,0}+p_{0,1}p_{1,3}p_{3,0}+p_{0,2}p_{2,0}+p_{0,2}p_{2,4}p_{4,0}$

$= \{\lambda_1/(\lambda_1+\lambda_3)\}/[\{(w_2)/(\lambda_2+w_2)\}+\{\lambda_2/(\lambda_2+w_2)\}]+\{\lambda_3/(\lambda_1+\lambda_3)\}/[\{(w_4)/(\lambda_4+w_4)\}$

$+\{\lambda_4/(\lambda_4+w_4)\}]$

$= [\{\lambda_1/(\lambda_1+\lambda_3)\}+\{\lambda_3/(\lambda_1+\lambda_3)\}] = 1$, $V_{0,1} = (0,1) = p_{0,1} = \{\lambda_1/(\lambda_1+\lambda_3)\}$

$V_{0,2} = (0,2) = p_{0,2} = \{\lambda_3/(\lambda_1+\lambda_3)\}$, $V_{0,3} = (0,1,3) = p_{0,1}\, p_{1,3} = \{\lambda_1\lambda_2/(\lambda_1+\lambda_3)(\lambda_2+w_2)\}$

$V_{0,4} = (0,2,4) = p_{0,2}\, p_{2,4} = \{\lambda_3\lambda_4/(\lambda_1+\lambda_3)(\lambda_4+w_4)\}$

MTSF (T_0): The regenerative un-failed states to which the system can transit (initial state '0'), before entering any failed state are: 'i' = 0,1,2 taking 'ξ' = '0'.

$$\text{MTSF } (T_0) = \left[\Sigma_{i,sr}\left\{\frac{\left\{pr\left(\xi\xrightarrow{sr(sff)}i\right)\right\}\mu i}{\Pi_{m_1\neq\xi}\{1-V_{\overline{m_1m_1}}\}}\right\}\right] \div \left[1-\Sigma_{sr}\left\{\frac{\left\{pr\left(\xi\xrightarrow{sr(sff)}\xi\right)\right\}}{\Pi_{m_2\neq\xi}\{1-V_{\overline{m_2m_2}}\}}\right\}\right]$$

$T_0 = (V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2)/\{1-(0,1,0)-(0,2,0)\}$

$= (V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2)/(1- p_{0,1}p_{1,0}- p_{0,2}p_{2,0})$

$= (K_1+K_2+K_3)/(1-p_{0,1}p_{1,0}- p_{0,2}p_{2,0})$, where $K_1 = V_{0,0}\mu_0$, $K_2 = V_{0,1}\mu_1$, $K_3 = V_{0,2}\mu_2$

Availability of the System (A_0): The regenerative states at which the system is available are 'j' = 0, 1, 2 and the regenerative states are 'i' = 0,1,2,3,4 taking 'ξ' = '0' the total fraction of time for which the system is available is given by

$$A_0 = \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\rightarrow}j)\}fj,\mu j}{\Pi_{m_1\neq\xi}\{1-V_{\overline{m_1m_1}}\}}\right\}\right] \div \left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\rightarrow}i)\}\mu_i^1}{\Pi_{m_2\neq\xi}\{1-V_{\overline{m_2m_2}}\}}\right\}\right]$$

$$A_0 = \left[\Sigma_j V_{\xi,j}, f_j, \mu_j\right] \div \left[\Sigma_i V_{\xi,i}, f_j, \mu_i^1\right]$$

$A_0 = (V_{0,0}f_0\mu_0+V_{0,1}f_1\mu_1+V_{0,2}f_2\mu_2)/(V_{0,0}\mu_0^1+V_{0,1}\mu_1^1+V_{0,2}\mu_2^1+V_{0,3}\mu_3^1+V_{0,4}\mu_4^1)$

As $f_j = 1$, for j = 0,1,2 and $f_j = 0$ for j = 3,4 Taking $\mu_i^1 = \mu_i$

Let $K = (V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,3}\mu_3+V_{0,4}\mu_4) = K_1+K_2+K_3+K_4+K_5$

$= (V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2)/K$, $= (K_1+K_2+K_3)/K$

Busy Period of the Server: The regenerative states are $1 \leq j \leq 4$ where server is busy while doing repairs and regenerative states are 'i' = 0 to 4 taking ξ = '0', the total fraction of time for which the server remains busy is

$$B_0 = \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\rightarrow}j)\},nj}{\Pi_{m_1\neq\xi}\{1-V_{\overline{m_1m_1}}\}}\right\}\right] \div \left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\rightarrow}i)\}\mu_i^1}{\Pi_{m_2\neq\xi}\{1-V_{\overline{m_2m_2}}\}}\right\}\right]$$

$$B_0 = \left[\Sigma_j V_{\xi,j}, n_j\right] \div \left[\Sigma_i V_{\xi,i}, \mu_i^1\right]$$

$B_0 = (V_{0,1}\eta_1+V_{0,2}\eta_2+V_{0,3}\eta_3+V_{0,4}\eta_4)/(V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,3}\mu_3+V_{0,4}\mu_4)$

Taking $\eta_i = \mu_i \ \forall\ i$

$= \{1-(V_{0,0}\mu_0)/K\}$, $= (1-\mu_0/K)$, $= (1-K_1/K)$

Expected Number of Inspections by the repair man: The regenerative states where the repair man do this job j = 1,2 the regenerative states are i = 0 to 4, Taking 'ξ' = '0', the number of visit by the repair man is given by

$$V_0 = \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\rightarrow}j)\}}{\Pi_{k_1\neq\xi}\{1-V_{\overline{k_1k_1}}\}}\right\}\right] \div \left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\rightarrow}i)\}\mu_i^1}{\Pi_{k_2\neq\xi}\{1-V_{\overline{k_2k_2}}\}}\right\}\right]$$

$$V_0 = \left[\Sigma_j V_{\xi,j}\right] \div \left[\Sigma_i V_{\xi,i}, \mu_i^1\right]$$

$V_0 = (V_{0,1}+V_{0,2})/(V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,3}\mu_3+V_{0,4}\mu_4)$

$= (V_{0,1}+V_{0,2})/K$, $= [\{\lambda_1/(\lambda_1+\lambda_3)\}+\{\lambda_3/(\lambda_1+\lambda_3)\}]/K$, $= 1/K$

Particular Cases

Warm Stand -by Case

$K = K_1+K_2+K_3+K_4+K_5$ $\quad K_1 = V_{0,0}\mu_0 = \{1/(\lambda_1+\lambda_3)\}$

$K_2 = V_{0,1}\mu_1 = \{\lambda_1/(\lambda_1+\lambda_3)(\lambda_2+w_2)\}$, $\quad K_3 = V_{0,2}\mu_2 = \{\lambda_3/(\lambda_1+\lambda_3)(\lambda_4+w_4)\}$

$K_4 = V_{0,3}\mu_3 = \{\lambda_1\lambda_2/(\lambda_1+\lambda_3)(\lambda_2+w_2)w_1\}$, $\quad K_5 = V_{0,4}\mu_4 = \{\lambda_3\lambda_4/(\lambda_1+\lambda_3)(\lambda_4+w_4)\}$

$p_{0,1}\, p_{1,0} = \{\lambda_1 w_2/(\lambda_1+\lambda_3)(\lambda_2+w_2)\}$, $\quad p_{0,2}\, p_{2,0} = \{\lambda_3 w_4/(\lambda_1+\lambda_3)(\lambda_4+w_4)\}$

$\lambda_3 = \lambda_4 = 0.001$

Table 6: MTSF Table

T_0	w = 0.90	w = 0.95	w = 1
$\lambda_1 = \lambda_2 = 0.4$	10.63309	10.94549	11.25837
$\lambda_1 = \lambda_2 = 0.3$	16.68000	17.23551	20.56375
$\lambda_1 = \lambda_2 = 0.2$	32.52569	33.77386	35.02725
$\lambda_1 = \lambda_2 = 0.1$	110.07734	115.08004	120.09520

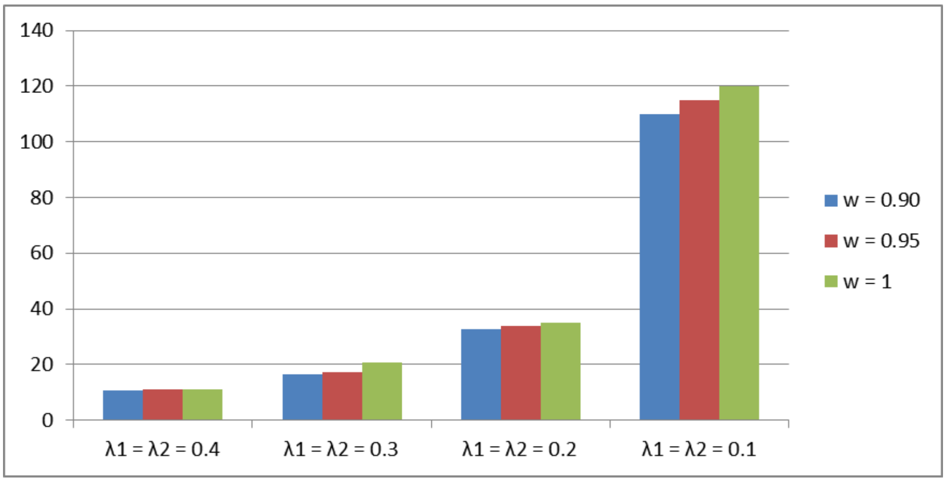


Fig 2: MTSF Graph

From the above table and graph we see that on decrease in the failure rate MTSF increases and on increasing the repair rate MTSF increase which should be so.

Table 7: Availability of the System Table

A_0	w = 0.90	w = 0.95	w = 1
$\lambda_1 = \lambda_2 = 0.4$	0.90539	0.91227	0.91842
$\lambda_1 = \lambda_2 = 0.3$	0.93755	0.94244	0.94714
$\lambda_1 = \lambda_2 = 0.2$	0.96697	0.96978	0.97224
$\lambda_1 = \lambda_2 = 0.1$	0.99000	0.99093	0.99174

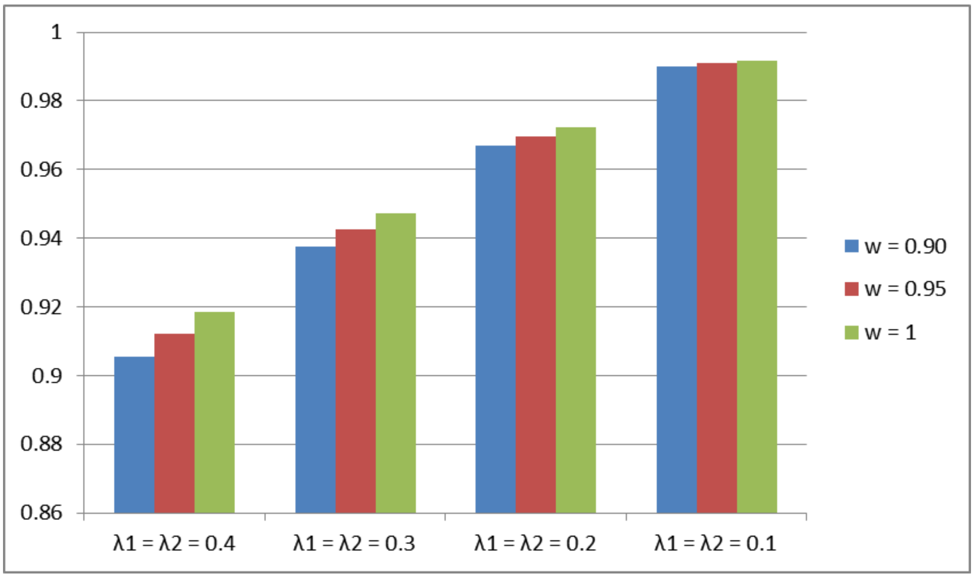


Fig 3: Availability of the System Graph

From the above table and graph we see that on decrease in the failure rate availability increases and on increasing the repair rate availability increase which should be so.

Busy Period of the Server (B_0)

Table 8: Busy Period of the Server Table

B_0	w = 0.90	w = 0.95	w = 1
$\lambda_1 = \lambda_2 = 0.4$	0.30822	0.29681	0.28622
$\lambda_1 = \lambda_2 = 0.3$	0.25062	0.24060	0.23658
$\lambda_1 = \lambda_2 = 0.2$	0.18255	0.17462	0.16735
$\lambda_1 = \lambda_2 = 0.1$	0.10089	0.09609	0.09173

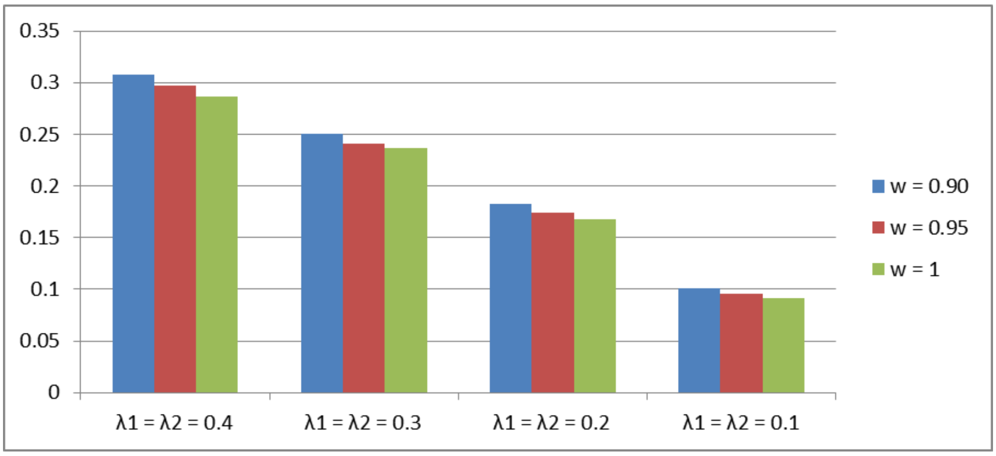


Fig 4: Busy Period of the Server Graph

From the above table and graph we see that on decrease in the failure rate busy period decrease and on increasing the repair rate busy period increase which should be so.

Expected Number of Server Visits V_0

Table 9: Expected Number of Server Visits Table

V_0	w = 0.90	w = 0.95	w = 1
$\lambda_1 = \lambda_2 = 0.4$	0.27740	0.28197	0.28622
$\lambda_1 = \lambda_2 = 0.3$	0.22556	0.22857	0.22978
$\lambda_1 = \lambda_2 = 0.2$	0.16430	0.16589	0.16736
$\lambda_1 = \lambda_2 = 0.1$	0.09080	0.09129	0.09173

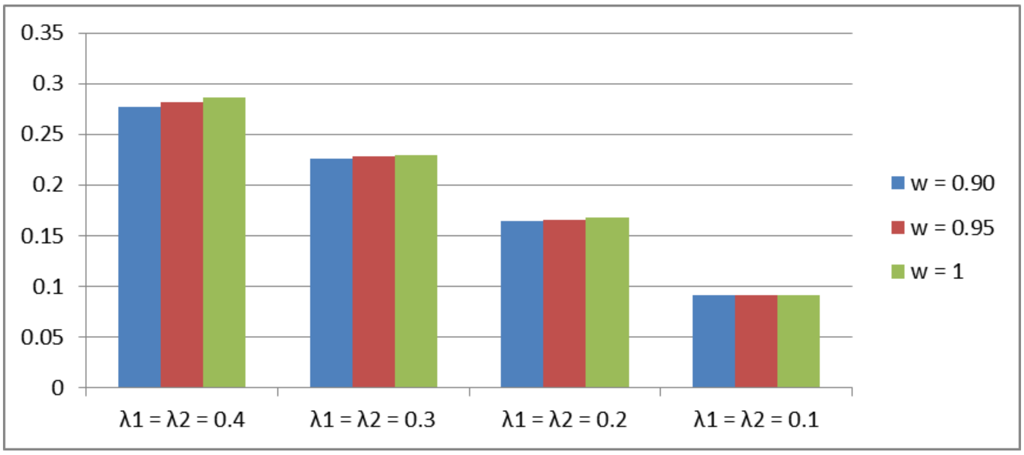


Fig 5: Expected Number of Server Visits Graph

Hot Stand by Case

$\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda$, $\quad w_1 = w_2 = w_3 = w_4 = w$

$K = K_1 + K_2 + K_3 + K_4 + K_5$

$K_1 = (1/2\lambda)$, $\quad K_2 = 1/2(\lambda+w)$, $\quad K_3 = 1/2(\lambda+w)$, $\quad K_4 = \lambda/2(\lambda+w)$

$K_5 = \lambda/2(\lambda+w)$, $\quad p_{0,1}\, p_{1,0} = w/2(\lambda+w)$, $\quad p_{0,2}\, p_{2,0} = w/2(\lambda+w)$

Table 10: MTSF Table

T_0	w = 0.90	w = 0.95	w = 1
$\lambda = 0.4$	6.56187	6.71866	6.87484
$\lambda = 0.3$	9.99912	10.27775	10.55498

λ = 0.2	18.74769	19.37419	19.99832
λ = 0.1	60.00000	62.49874	64.99208

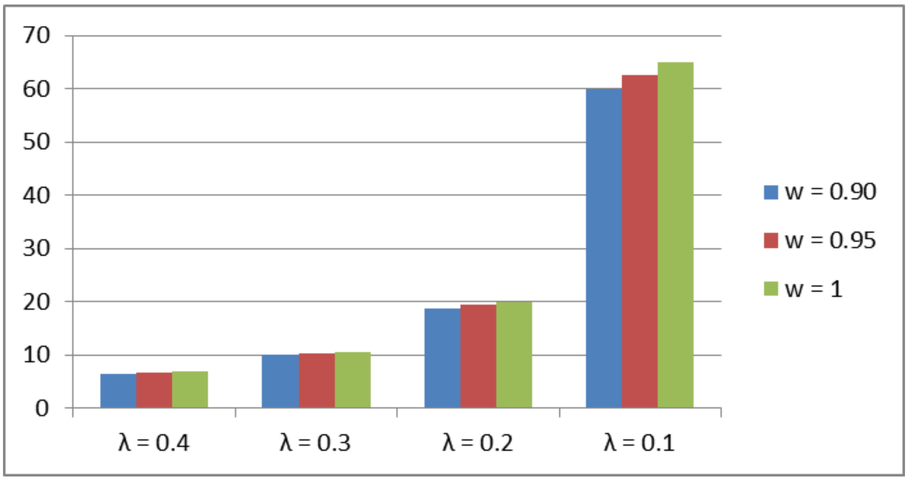


Fig 6: MTSF Graph

Availability of the System (A_0)

Table 11: Availability of the System Table

A_0	w = 0.90	w = 0.95	w = 1
λ = 0.4	0.86777	0.87045	0.87302
λ = 0.3	0.90909	0.91132	0.91346
λ = 0.2	0.94937	0.95092	0.95238
λ = 0.1	0.98360	0.98425	0.98484

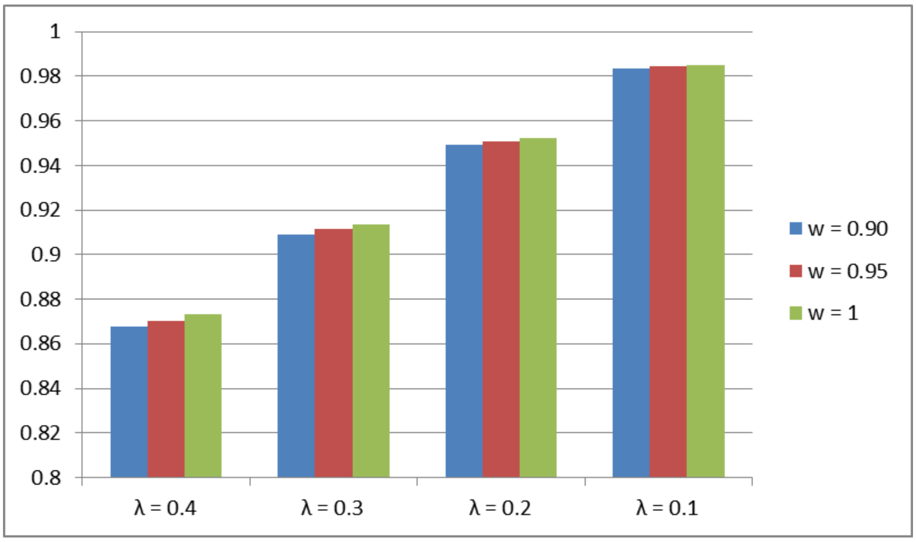


Fig 7: Availability of the System Graph

Busy Period of the Server (B_0)

Table 12: Busy Period of the Server Table

B_0	w = 0.90	w = 0.95	w = 1
λ = 0.4	0.46280	0.45343	0.44443
λ = 0.3	0.39393	0.38423	0.37499
λ = 0.2	0.30379	0.29447	0.28571
λ = 0.1	0.18032	0.17322	0.16666

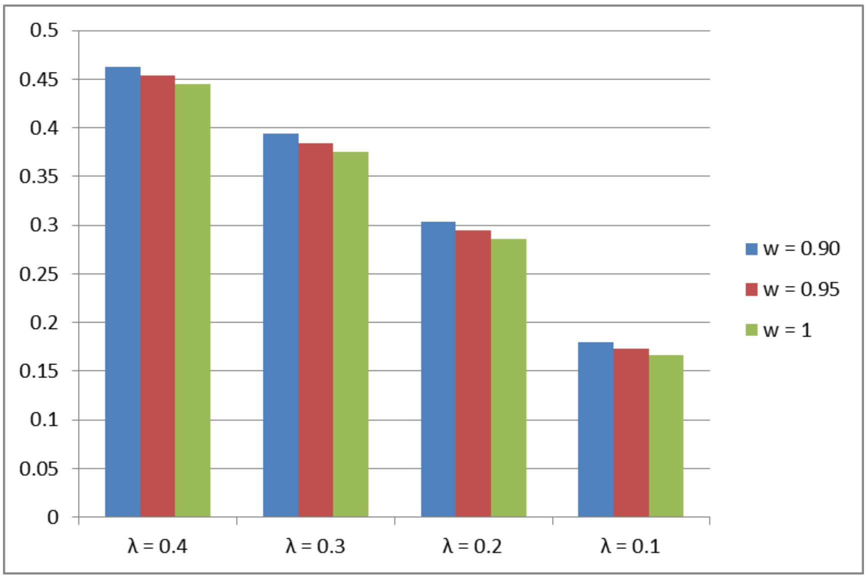


Fig 8: Busy Period of the Server Graph

Expected Number of Server's Visits (V_0)

Table 13: Expected Number of Server's Visits Table

V_0	w = 0.90	w = 0.95	w = 1
λ = 0.4	0.42975	0.43725	0.44444
λ = 0.3	0.36363	0.36945	0.37500
λ = 0.2	0.27848	0.28221	0.28571
λ = 0.1	0.16393	0.16535	0.16666

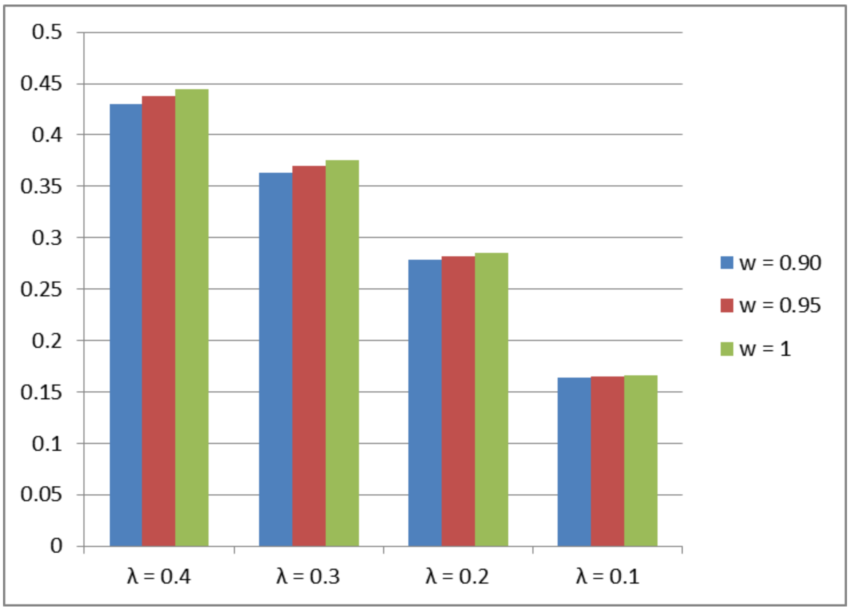


Fig 9: Expected Number of Server's Visits Graph

Cold Stand by Case

$\lambda_1 = \lambda_2 = \lambda$, $\lambda_3 = \lambda_4 = 0$, $w_1 = w_2 = w$, $w_3 = w_4 = 1$

$K = K_1 + K_2 + K_3 + K_4 + K_5$

$K_1 = \mu_0 = (1/\lambda)$, $K_2 = V_{0,1}\, \mu_1 = 1/(\lambda+w)$, $K_3 = 0$, $K_4 = \lambda/(\lambda+w)$

$K_5 = 0$, $p_{0,1}\, p_{1,0} = w/(\lambda+w)$, $p_{0,2}\, p_{2,0} = 0$

Table 14: MTSF

T_0	w = 0.90	w = 0.95	w = 1
λ = 0.4	10.62473	10.93736	11.24975
λ = 0.3	16.66664	17.22220	17.77770
λ = 0.2	32.49967	33.74862	34.99928
λ = 0.1	110.00000	114.99769	120.01199

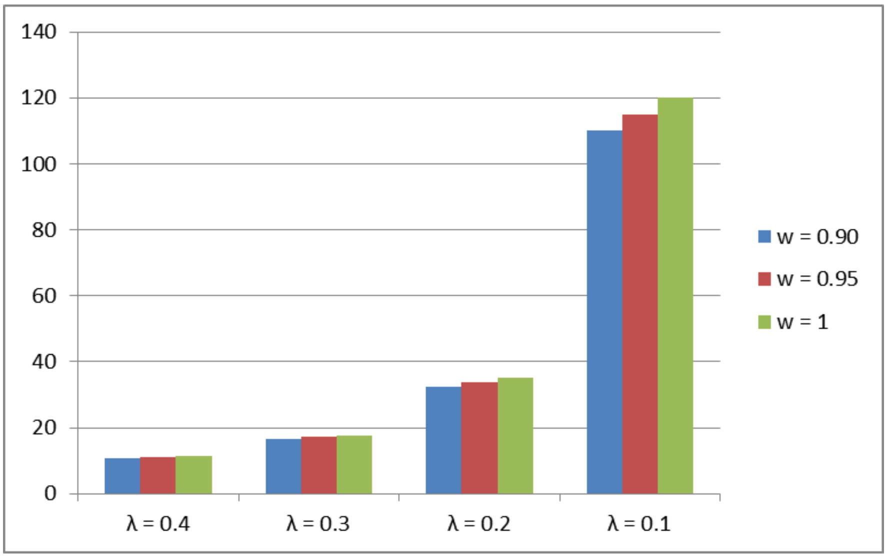


Fig 10: MTSF Graph

Availability of the System (A_0)

Table 15: Availability of the System

A_0	w = 0.90	w = 0.95	w = 1
λ = 0.4	0.91397	0.91623	0.91836
λ = 0.3	0.94339	0.94512	0.94674
λ = 0.2	0.97015	0.97122	0.97222
λ = 0.1	0.99099	0.99138	0.99173

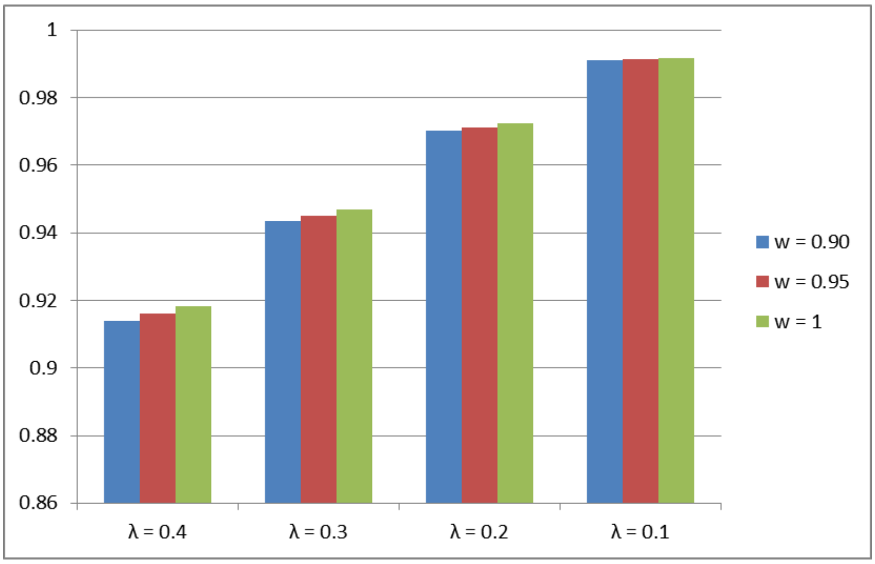


Fig 11: Availability of the System Graph

Busy Period of the Server (B_0)

Table 16: Busy Period of the Server

B_0	w = 0.90	w = 0.95	w = 1
λ = 0.4	0.30107	0.29319	0.28571
λ = 0.3	0.24528	0.23780	0.23076
λ = 0.2	0.17910	0.17266	0.16666
λ = 0.1	0.09909	0.09482	0.09090

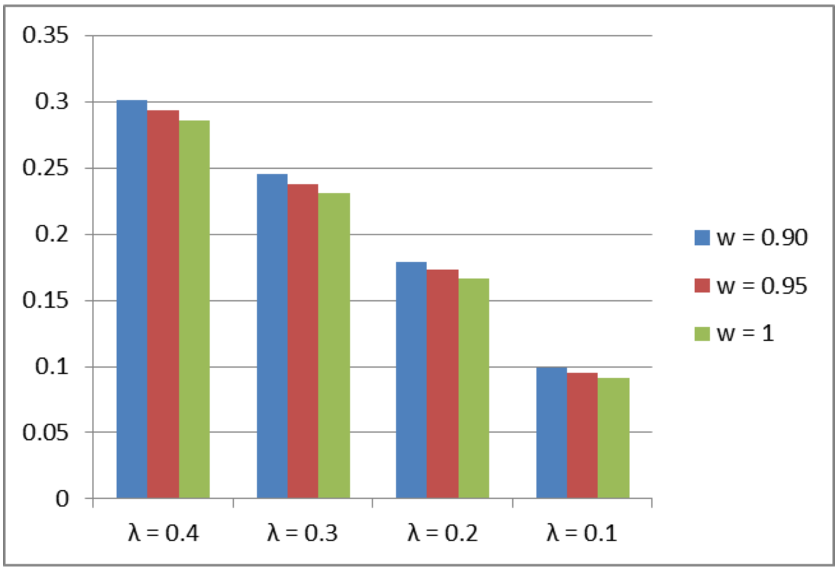


Fig 12: Busy Period of the Server Graph

Expected Number of Server's Visits (V_0)

Table 17: Expected Number of Server's Visits Table

V_0	w = 0.90	w = 0.95	w = 1
λ = 0.4	0.27957	0.28272	0.28571
λ = 0.3	0.22641	0.22865	0.23076
λ = 0.2	0.16417	0.16546	0.16666
λ = 0.1	0.09009	0.09051	0.09090

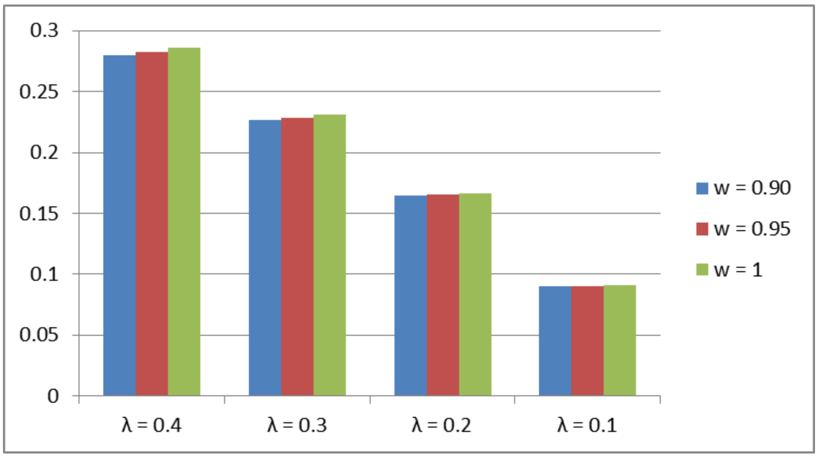


Fig 13: Expected Number of Server's Visits Graph

Conclusion: from the results of warm, cold and hot standby the results for systems parameters depict the practical trends which should be there**.**

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