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Availability analysis of poultry, cattle and fish feed plant

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Abstract
In this paper, system parameters of Poultry, Cattle and Fish Feed Plant are analyzed using Regenerative Point Graphical Technique (RPGT). Plant consists of three grinders which grind three different raw material to powder form depending upon the feed to be prepared, together with a single cold standby for all these grinders, one mixer which compounds that powder with molasses and weighing & packing unit. When the standby unit is online system works in reduced capacity. On failure of standby unit or mixer or packing repair unit, the system fails. Taking failure and repair rates exponential problem is formulated and solved using RPGT. Taking various probability considerations a transition diagram depicting the possible states in which system can stay is drawn, transition probabilities and mean so-journ times evaluated, the system is discussed for steady state conditions. Particular cases are taken, tables and graphs are also prepared to discuss the practical trend of the system.

Keywords: Availability, Regenerative Point Graphical Technique (RPGT), System Parameters, Base State.

Introduction

In a poultry cattle and fish feed plant various raw materials used are maize, rice-bran, groundnuts, etc. The plant has three grinders, A_1, A_2, A_3 which grinders (powders) the raw materials there is a cold standby grinder A for all three switched in by a perfect switch-over device upon failure of any one of these three grinders, a mixer unit B which compounds the raw materials in the required proportion with molasses and a weighing & packing unit. 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, V. K., Singh, J. & Kumar Kuldeep [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 systems behavior with perfect and imperfect switch-over of systems using various techniques.

When the standby unit is online system works in reduced capacity. On failure of standby unit or mixer or packing repair unit, the system fails. Taking failure and repair rates exponential problem is formulated and solved using RPGT. Taking various probability considerations a transition diagram depicting the possible states in which system can stay is drawn, transition probabilities and mean so-journ time evaluated, the system parameters are discussed for steady state conditions. Particular cases are taken tables and graphs are also prepared to discuss the practical trend of the system.

Assumptions and Notations: - The following assumptions and notations are taken: -

1. No unit can fail further when the system is in failed state.
2. There is a single repairman for repair of failed units and in reduced states.
3. The failure rates are exponentially distributed and repair rate are general and are independent and are different for different operative units.
4. Repair of units is perfect i.e. repaired unit works as a new one.
5. The system is down when any of the units is in failed state.
6. The system is discussed for steady state conditions.

7. Failure and repaired are independent.
8. Unit A may work in reduced capacity.
9. There is uninterrupted power supply and no two units fail simultaneously.

$\overline{cycle}$: 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-$\overline{\text{cycle}}$: 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-$\overline{\text{cycle}}$.

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 t 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.

η_i : 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_i : Constant failure rate of systems etc.

A/a : Unit in full capacity working / failed state of units A, similarly for unit B and D.

W_i : are constant repair rates of units.

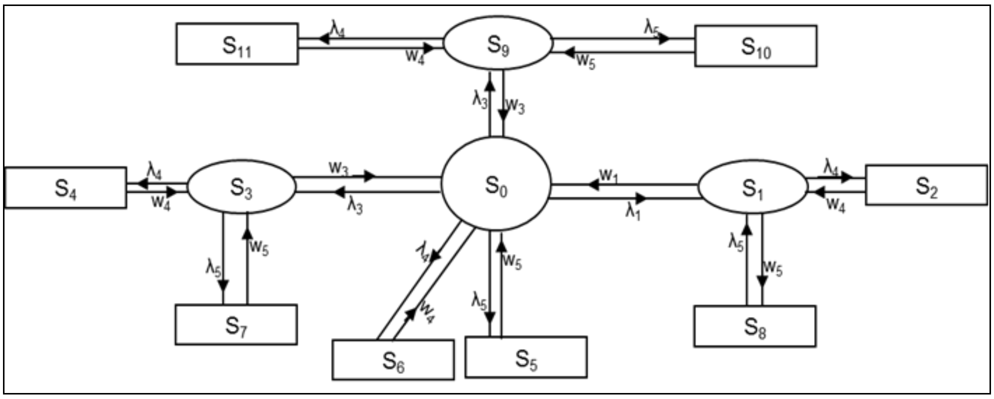
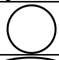
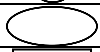


Fig 1

Where

S_0	=	$A_1A_2A_3BD(A)$,
S_1	=	$AA_2A_3BD(a_0)$,
S_2	=	$AA_2A_3bD(a_1)$,
S_3	=	$A_1AA_3BD(a_2)$,
S_4	=	$A_1A_2AbD(a_3)$,
S_5	=	$A_1A_2A_3Bd$
S_6	=	$A_1A_2A_3bD$,
S_7	=	$A_1AA_3Bd(a_2)$,
S_8	=	$AA_2A_3Bd(a_1)$
S_9	=	$A_1A_2ABD(a_3)$,
S_{10}	=	$A_1A_2ABd(a_3)$,
S_{11}	=	$A_1A_2AbD(a_3)$

Table 1

State	Symbol	Model
Regenerative State		0
Reduced State		1,3,9
Failed State		2,4,5,6,7,8,10,11

Primary, Secondary & Tertiary Circuits at the various Vertices

Table 2: As there are maximum number of primary cycles at vertex '0', hence base state is '0'.Primary, Secondary, Tertiary Circuits w.r.t. the Simple Paths (Base-State '0')

Vertex i	Primary Circuits	Secondary Circuits	Tertiary Circuits
0	(0,1,0) (0,3,0), (0,6,0) (0,9,0), (0,5,0)	(1,2,1), (1,5,1) (3,7,3), (3,4,3) Nil	Nil Nil Nil
1	(1,0,1), (1,8,1) (1,2,1)	(0,3,0), (0,6,0) (0,9,0), (0,5,0)	(3,5,3), (3,4,3) (9,10,9), (9,11,9)
2	(2,1,2)	(1,0,1), (1,8,1)	(0,9,0), (0,5,0) (0,6,0), (0,3,0)
3	(3,0,3) (3,7,3) (3,4,3)	(0,1,0), (0,5,0) (0,6,0), (0,9,0)	(1,2,1), (1,8,1)
4	(4,3,4)	(3,7,3), (3,0,3)	(0,1,0), (0,9,0) (0,6,0), (0,5,0)
5	(5,0,5)	(0,6,0), (0,3,0) (0,9,0), (0,1,0)	(3,7,3), (3,4,3) (9,10,9), (9,11,9)
6	(6,0,6)	(0,5,0), (0,1,0) (0,3,0), (0,9,0)	(1,8,1), (1,2,1)
7	(7,3,7)	(3,0,3), (3,4,3)	(0,9,0), (0,1,0) (0,5,0), (0,6,0)
8	(8,1,8)	(1,0,1), (1,2,1)	(0,5,0), (0,6,0) (0,3,0), (0,9,0)
9	(9,0,9) (9,10,9) (9,11,9)	(0,1,0), (0,5,0) (0,6,0), (0,3,0)	(1,8,1), (1,2,1) (3,7,3), (3,4,3)
10	(10,9,10)	(9,0,9) (9,11,9)	(0,1,0), (0,5,0) (0,6,0), (0,3,0)
11	(11,9,11)	(9,0,9) (9,10,9)	(0,1,0), (0,5,0) (0,6,0), (0,3,0)

Table 3

Vertex j	$\left(3 \xrightarrow{S_r} j\right)$: (P0)	(P1)	(P2)
0	$\left(0 \xrightarrow{S_1} 0\right)$: (0,1,0), (0,6,0) (0,3,0) (0,9,0) (0,5,0)	(1,2,1) (1,8,1) (3,7,3), (3,4,3) (9,10,9), (9,11,9)	Nil Nil Nil Nil
1	$\left(0 \xrightarrow{S_1} 1\right)$: (0,1)	(1,2,1), (1,8,1)	Nil
2	$\left(0 \xrightarrow{S_1} 2\right)$: (0,1,2)	(1,8,1)	Nil
3	$\left(0 \xrightarrow{S_1} 3\right)$: (0,3)	(3,7,3), (3,4,3)	Nil
4	$\left(0 \xrightarrow{S_1} 4\right)$: (0,3,4)	(3,7,3)	Nil
5	$\left(0 \xrightarrow{S_1} 5\right)$: (0,5)	Nil	Nil
6	$\left(0 \xrightarrow{S_1} 6\right)$: (0,6)	Nil	Nil
7	$\left(0 \xrightarrow{S_1} 7\right)$: (0,3,7)	(3,4,3)	Nil
8	$\left(0 \xrightarrow{S_1} 8\right)$: (0,1,8)	(1,2,1)	Nil

9	$\left(0 \xrightarrow{S_1} 9\right)$: (0,9)	(9,10,9), (9,11,9)	Nil
10	$\left(0 \xrightarrow{S_1} 10\right)$: (0,9,10)	(9,11,9)	Nil
11	$\left(0 \xrightarrow{S_1} 11\right)$: (0,9,11)	Nil	Nil

Transition Probability and the Mean sojourn times.

$q_{i,j}(t)$ **:** 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

$q_{i,j}^{(t)}$	$P_{ij} = q^{*}_{i,j}{}^{(t)}$
$q_{0,1} = \lambda_1 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$ $q_{0,5} = \lambda_5 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$ $q_{0,6} = \lambda_6 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$ $q_{0,3} = \lambda_2 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$ $q_{0,9} = \lambda_3 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$	$p_{0,1} = \lambda_1/(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)$ $p_{0,5} = \lambda_5/(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)$ $p_{0,6} = \lambda_6/(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)$ $p_{0,3} = \lambda_2/(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)$ $p_{0,9} = \lambda_3/(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)$
$q_{1,2} = \lambda_4 e^{-(\lambda_4+\lambda_5+w_1)t}$ $q_{1,8} = \lambda_5 e^{-(\lambda_4+\lambda_5+w_1)t}$ $q_{1,0} = w_1 e^{-(\lambda_4+\lambda_5+w_1)t}$	$p_{1,2} = \lambda_4/(\lambda_2+\lambda_5+w_1)$ $p_{1,8} = \lambda_5/(\lambda_2+\lambda_5+w_1)$ $p_{1,0} = w_1/(\lambda_2+\lambda_5+w_1)$
$q_{2,1} = w_4 e^{-w_4 t}$	$p_{2,1} = w_4/w_4 = 1$
$q_{3,0} = w_2 e^{-(w_2+\lambda_5+\lambda_4)t}$ $q_{3,7} = \lambda_5 e^{-(w_2+\lambda_5+\lambda_4)t}$ $q_{3,4} = \lambda_4 e^{-(w_2+\lambda_5+\lambda_4)t}$	$p_{3,0} = w_2/(w_2+\lambda_5+\lambda_4)$ $p_{3,7} = \lambda_5/(w_2+\lambda_5+\lambda_4)$ $p_{3,4} = \lambda_4/(w_2+\lambda_5+\lambda_4)$
$q_{4,3} = w_4 e^{-w_4 t}$	$p_{4,3} = 1$
$q_{5,0} = w_5 e^{-w_5 t}$	$p_{5,0} = 1$
$q_{6,0} = w_4 e^{-w_4 t}$	$p_{6,0} = 1$
$q_{7,3} = w_5 e^{-w_5 t}$	$p_{7,3} = 1$
$q_{8,1} = w_5 e^{-w_5 t}$	$p_{8,1} = 1$
$q_{9,0} = w_3 e^{-(w_3+\lambda_5+\lambda_4)t}$ $q_{9,10} = \lambda_5 e^{-(w_3+\lambda_5+\lambda_4)t}$ $q_{9,11} = \lambda_4 e^{-(w_3+\lambda_5+\lambda_4)t}$	$p_{9,0} = w_3/(w_3+\lambda_5+\lambda_4)$ $p_{9,10} = \lambda_5/(w_3+\lambda_5+\lambda_4)$ $p_{9,11} = \lambda_4/(w_3+\lambda_5+\lambda_4)$
$q_{10,9} = w_5 e^{-w_4 t}$	$p_{10,9} = 1$
$q_{11,9} = w_4 e^{-w_4 t}$	$p_{11,9} = 1$

$V_{0,0} = 1$ (Verified)
$V_{0,1} = (0,1)/[1-(1,21)][1-(1,8,1)]$
$= p_{0,1}/(1-p_{1,2}p_{2,1})(1-p_{1,8}p_{8,1})$
$V_{0,2} = (0,1,2)/[1-(1,8,1)]$
$= p_{0,1}/(1-p_{1,8}p_{8,1})$
$= [\{\lambda_1/(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)\}\{\lambda_4/(\lambda_4+\lambda_5+w_1)\}]$
$/[\{1-(\lambda_5/\lambda_4+\lambda_5+w_1)\}]$

Mean Sojourn Times

$R_i(t)$	$\mu_i = R_i^*(0)$
$R_0^{(t)} = e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$	$\mu_0 = 1/(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)$
$R_1^{(t)} = e^{-(\lambda_4+\lambda_5+W_1)t}$	$\mu_1 = 1/(\lambda_4+\lambda_5+w_1)$
$R_2^{(t)} = e^{-(w_4)t}$	$\mu_2 = 1/(w_4)$
$R_3^{(t)} = e^{-(w_2+\lambda_5+\lambda_4)t}$	$\mu_3 = 1/(w_2+\lambda_5+\lambda_4)$
$R_4^{(t)} = e^{-w_4 t}$	$\mu_4 = 1/w_4$
$R_5^{(t)} = e^{-w_5 t}$	$\mu_5 = 1/w_5$
$R_6^{(t)} = e^{-(w_4)t}$	$\mu_6 = 1/(w_4)$
$R_7^{(t)} = e^{-(w_5)t}$	$\mu_7 = 1/(w_5)$
$R_8^{(t)} = e^{-w_5 t}$	$\mu_8 = 1/w_5$
$R_9^{(t)} = e^{-(w_3+\lambda_5+\lambda_4)t}$	$\mu_9 = 1/(w_3+\lambda_5+\lambda_4)$
$R_{10}^{(t)} = e^{-w_5 t}$	$\mu_{10} = 1/w_5$
$R_{11}^{(t)} = e^{-(w_4)t}$	$\mu_{11} = 1/(w_4)$

$V_{0,3}$ = (0,3)/[1-(3,7,3)][1-(3,4,3)],= $p_{0,3}/(1-p_{3,7}p_{7,3})(1-p_{3,4}p_{4,3})$ =[{$\lambda_2/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$}]/[{1-$\lambda_5(w_2+\lambda_5+\lambda_4)$}{1-$\lambda_4(w_2+\lambda_5+\lambda_4)$}]

$V_{0,4}$ = (0,3,4)/[1-(3,7,3)], = $p_{0,3}p_{3,4}/(1-p_{3,7}p_{7,3})$ = [{$\lambda_2/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$} {$\lambda_4(w_2+\lambda_5+\lambda_4)$}] / [{1-$\lambda_5(w_2+\lambda_5+\lambda_4)$}]

$V_{0,5}$ = (0,5), = $p_{0,5}$ = [{$\lambda_5/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$}]

$V_{0,6}$ = (0,6), = $p_{0,6}$ = [{$\lambda_4/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$}]

$V_{0,7}$ = (0,3,7)/[1-(3,4,3)], = $p_{0,3}p_{3,7}/(1-p_{3,4}p_{4,3})$= [{$\lambda_2/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$} {$\lambda_5(w_2+\lambda_5+\lambda_4)$}] / [{1-$\lambda_4(w_2+\lambda_5+\lambda_4)$}]

$V_{0,8}$ = (0,1,8)/[1-(1,2,1)], = $p_{0,1}p_{1,8}/(1-p_{0,1}p_{1,8})$ = [{$\lambda_1/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$}{$\lambda_5(w_1+\lambda_4+\lambda_5)$}] / [{1-$\lambda_4(w_1+\lambda_4+\lambda_5)$}]

$V_{0,9}$ = (0,9)/[1-(9,10,9)][1-(9,11,9)], = $p_{3,9}/(1-p_{9,10}p_{10,9})(1-p_{9,11}p_{11,9})$= [{$\lambda_3/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$}] / [{1-$\lambda_5(w_3+\lambda_5+\lambda_4)$} [{1-$\lambda_4(w_3+\lambda_4+\lambda_5)$}]

$V_{0,10}$ = (0,9,10)/[1-(9,11,9)], = $p_{0,9}p_{9,10}/(1-p_{9,11}p_{11,9})$ = [{$\lambda_3/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$} {$\lambda_5(w_3+\lambda_5+\lambda_4)$}] / [{1-$\lambda_4(w_3+\lambda_5+\lambda_4)$}]

$V_{0,11}$ = (0,9,11)/[1-(9,0,9)], = $p_{0,9}p_{9,11}/(1-p_{9,0}p_{0,9})$ = [{$\lambda_3/(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5)$}{$\lambda_4(w_3+\lambda_5+\lambda_4)$}]

Mean Time To System Failure (T_0): The regenerative un-failed states to which the system can transit (initial state '0'), before entering any failed state are: 'i' = 0,1,3,9

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

$= (V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,3}\mu_3+V_{0,9}\mu_9)$

Availability of the System (A_0): The regenerative states at which the system is available are 'j' = 0,1,3,9 and the regenerative states are 'i' = 0 to 11 taking 'ξ' = '0' the total fraction of time for which the system is available is given by

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

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

$= (V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,3}\mu_3+V_{0,9}\mu_9)/(V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,3}\mu_3+V_{0,4}\mu_4+V_{0,5}\mu_5+V_{0,6}\mu_6+V_{0,7}\mu_7+V_{0,8}\mu_8+V_{0,9}\mu_9+V_{0,10}\mu_{10}+V_{0,11}\mu_{11})$

Busy Period of the Server (B_0): The regenerative states where server is busy are 'j' = 1 to 11, taking ξ = '0', the total fraction of time for which the server remains busy is

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

$= (V_{0,0}\mu_0+ V_{0,1}\mu_1+V_{0,2}\mu_2+ V_{0,3}\mu_3+V_{0,4}\mu_4+V_{0,5}\mu_5+V_{0,6}\mu_6+V_{0,7}\mu_7+V_{0,8}\mu_8+V_{0,9}\mu_9 +V_{0,10}\mu_{10}+V_{0,11}\mu_{11})/D$

Expected Number of Inspections by the repair man (V_0): The regenerative states where the repair man visits a fresh are j = 1, 3, 9 the regenerative states are i = 0 to 11, Taking 'ξ' = '0', the proportional number of visit by the repair man is given by

$$V_0 = \left[\sum_{j,sr}\left\{\frac{\{pr(\xi^{sr\to}j)\}}{\Pi_{k_1\neq\xi}\{1-V_{\overline{k_1 k_1}}\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr(\xi^{sr\to}i)\}\mu_i^1}{\Pi_{k_2\neq\xi}\{1-V_{\overline{k_2 k_2}}\}}\right\}\right] = \left[\sum_j V_{\xi,j}\right] \div \left[\sum_i V_{\xi,i}\,,\mu_i^1\right]$$

$= (V_{0,1}+V_{0,3}+V_{0,9})/D$

Particular Cases

$\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda,\quad w_1 = w_2 = w_3 = w_4 = w_5 = w$

$V_{0,0}$ = 1, $V_{0,1} = (\lambda/5\lambda)/[1-\lambda/(2\lambda+w)][1-\lambda/(2\lambda+w)]$

$V_{0,2}$ = $[(\lambda/5\lambda)(\lambda/2\lambda+w)]/[1-\lambda/2\lambda+w)]$, $V_{0,3} = (1/5)/[\{1-\lambda(2\lambda+w)\}\{1-\lambda(2\lambda+w)\}]$

$V_{0,4}$ = $[(1/5)\{\lambda/(2\lambda+w)\}]/[\{1-\lambda(2\lambda+w)\}]$,

$V_{0,5}$ = $(0/5)$,

$V_{0,6}$ = $(0/6)$

$V_{0,7}$ = $[(1/5)\{\lambda/(2\lambda+w)\}]/[\{1-\lambda(2\lambda+w)\}]$,

$V_{0,8}$ = $[(1/5)\{\lambda/(2\lambda+w)\}]/[\{1-\lambda(2\lambda+w)\}]$

$V_{0,9}$ = $[1/5]/[\{1-\lambda(2\lambda+w)\}\{1-\lambda(2\lambda+w)\}]$,

$V_{0,10}$ = $[(1/5)\{\lambda/(2\lambda+w)\}]/[\{1-\lambda(2\lambda+w)\}]$

$V_{0,11}$ = $[(1/5)\{\lambda/(2\lambda+w)\}]/[\{1-w(2\lambda+w)\}(1/5)]$

MTSF (T_0) = $(1/5)[\{1+3(2\lambda+w)\}/(\lambda + w)^2]$

Table 6: MTSF

T_0	w = 0.80	w = 0.85	w = 0.90	w = 0.95	w = 1
λ = 0.00	0.95	0.90	0.86	0.83	0.80
λ = 0.10	0.94	0.90	0.86	0.82	0.79
λ = 0.15	0.93	0.89	0.85	0.81	0.78

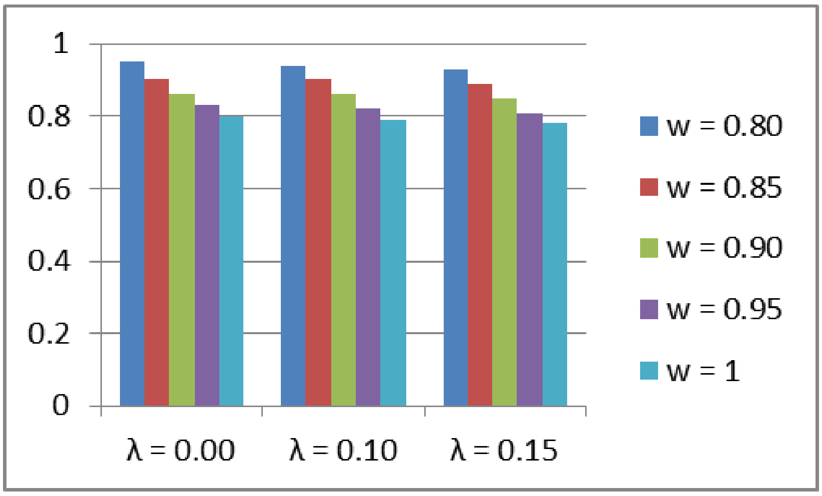


Fig 2

Availability of the System (A_0)

(A_0) = $(1/5D)\,[1+\{3(2\lambda+w)/(\lambda+w)^2\}]$

Where D = $(V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,3}\mu_3+V_{0,4}\mu_4+V_{0,5}\mu_5+V_{0,6}\mu_6+V_{0,7}\mu_7+V_{0,8}\mu_8+V_{0,9}\mu_9+V_{0,10}\mu_{10}+V_{0,11}\mu_{11})$

Availability of the System Table

Table 7

A_0	w = 0.80	w = 0.85	w = 0.90	w = 0.95	w = 1
λ = 0.00	0.95	0.96	0.97	0.98	1.00
λ = 0.10	0.39	0.38	0.37	0.37	0.36
λ = 0.15	0.31	0.30	0.29	0.28	0.27

Availability of the System Graph

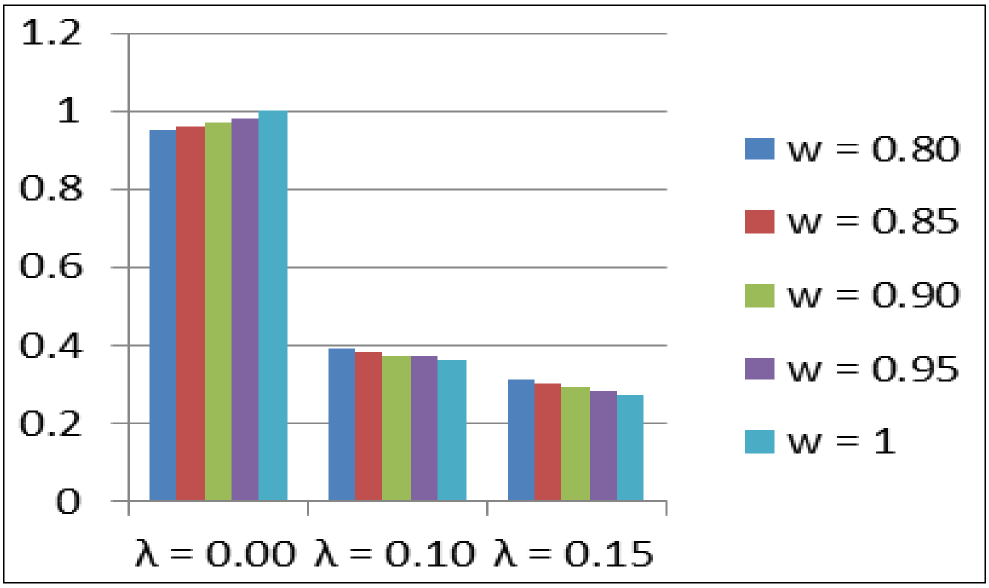


Fig 3

Busy Period of the Server (B_0) = $[1-(V_{0,0}\mu_0/D)]$, $= [1-(\mu_0/D)]$, $= [1-(1/5D)]$

Table 8: Busy Period of the Server

B_0	w = 0.80	w = 0.85	w = 0.90	w = 0.95	w = 1
λ = 0.00	0.80	0.78	0.77	0.76	0.75
λ = 0.10	0.91	0.91	0.91	0.90	0.90
λ = 0.15	0.93	0.93	0.93	0.92	0.92

Busy Period of the Server Graph

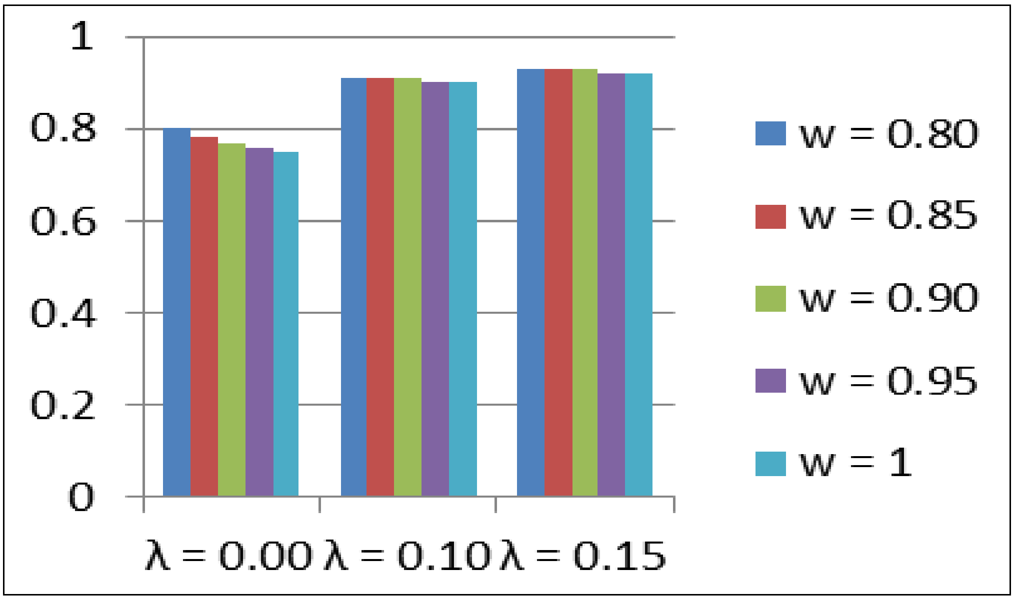


Fig 4

Expected Proportional Number of Server's Visits (V_0) = $[3(2\lambda+w)^2/5D(\lambda+w)^2]$

Table 9: Expected Proportional Number of Server's Visits

V_0	w = 0.80	w = 0.85	w = 0.90	w = 0.95	w = 1
λ = 0.00	0.34	0.35	0.35	0.36	0.36
λ = 0.10	0.24	0.25	0.25	0.25	0.25
λ = 0.15	0.60	0.63	0.68	0.71	0.75

Expected Number of Server's Visits Graph

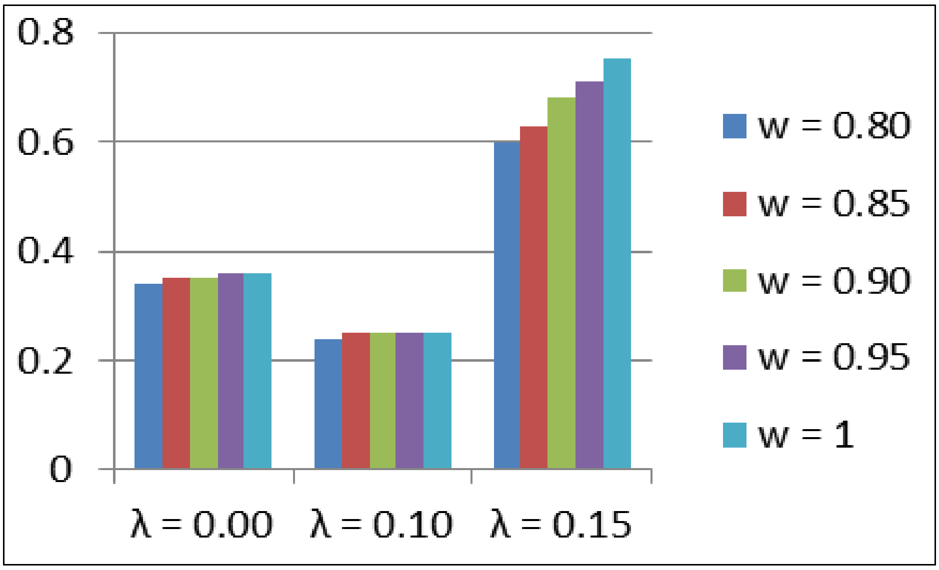


Fig 5

Profit Function = $A_0R_0-(B_0R_1+V_0R_2)$ = $A_0R_0-B_0R_1-V_0R_2$

Where, A_0 = Availability of System B_0 = Busy Period of Server

V_0 = Expected Number of Inspection by the Repair Man

R_0 = Revenue, R_1 = Busy Period per Unit,

R_2 = Cost per visit, R_0 = 1000

R_1 = 50, R_2 = 100

Table 10: Profit Function

	w = 0.80	**w = 0.85**	**w = 0.90**	**w = 0.95**	**w = 1**
λ = 0.00	840.00	850.50	859.00	868.50	887.50
λ = 0.10	205.00	194.50	184.50	175.50	165.50
λ = 0.15	282.00	271.50	261.50	262.00	252.00

Profit Function Graph

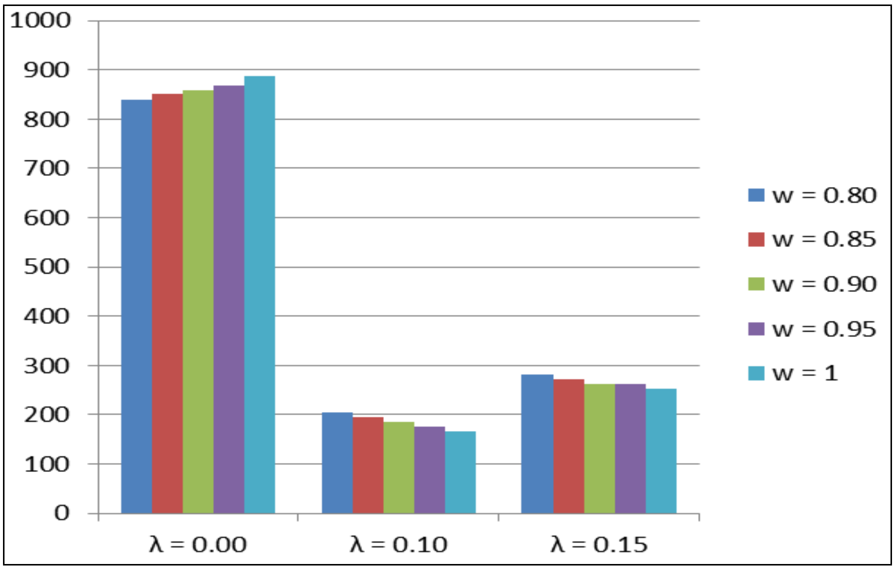


Fig 6

Conclusion

From above tables and graph we see that the result obtained using Regenerative Point Graphical Technique is same as obtained by using Regenerative Point Technique and other techniques. But in Regenerative Point Graphical Technique, we obtained the results very easily and quickly without writing any state equations and without any cumbersome procedures, long calculations and simplifications. Keeping the optimum or desired values of the system parameters and profit function repair rates may be determined easily to get these results.

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