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Profit Analysis of a Paint Manufacturing Plant using RPGT

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Abstract: In the current paper, we discussed a novel method for performance valuation of a paint manufacturing plant in which five subsystems are associated in series configuration. Taking failure and repair rates constant. A state diagram of the framework depicting the transition rates is drawn. RPGT is used to create expressions for path probabilities such as mean sojourn times, mean time to system failure, system availability, server busy period, and expected number of server visits. Using Regenerative Point Graphical Technique, a profit analysis of the system is performed, which may be valuable to management in sustaining the various components of the system (RPGT). To compare and draw a conclusion, tables and graphs are created.

Keywords: - RPGT, Profit Analysis, System Parameters

1. Introduction:

Modern products range from simple to complicated, thus bakeries, washing units, 3:4::G systems, and poly-tube plants should all have high-quality designs with high availability and system characteristics. In modern engineering paint factories, the competition and challenge is to ensure optimal manufacturing costs and a short design cycle time in order to achieve performance and dependability. The primary indices of performance analysis of engineering systems are always considered availability, busy period of repairman, and profit function. Profit analysis is used in this work to analyses transient behavior of a repairable paint production plant using RPGT, which is based on Markov modeling for system parameter equations.The impact of unit failure and repair is investigated in order to get the best possible performance of system characteristics. Process industry availability / maintainability analysis is becoming more important these days, which could benefit the sector by increasing production and lowering maintenance costs.

Kumar et al. (2018, 2017) have calculated the behavior analysis of a bread scheme and edible oil refinery plant. Sunita et al. (2021) studied on the Solution of constrained problems using particle swarm optimization.Kumar et al. (2019) analyzed a cold standby framework with priority for PM comprises two identical subunits with server disappointment utilizing RPGT. Gupta (2008), Garg et al. (2021), Chaudhary et al. (2013), Rajbala (2021), Goyal and Goel (2015), Yusuf (2012), Kumar and Garg (2019) and Gupta et al. (2016) have discussed behavior by perfect and imperfect switch-over of schemes utilizing various techniques.Asi et al. (2021) have carried out a relative exploration of the five productive reliability methods to start general rues for the probabilistic evaluation of bridge pier. Kumar et al. (2019) the main impartial of this paper is to an observed analysis of a washing unit in the paper industry utilizing RPGT.Rajbala and Kumar (2021) analyzed the reliability and availability analysis of the process industry using RPGT technique.

A full description of a paint manufacturing factory has been added to this section. Mixer (A), grinding mill (B), dilution (D), Labeling Machine (E), and filling machine (F) are the five subsystems that make up the system. The subsystems A, B, and D operate under the configuration 1-out-of-1: excellent policy, whereas E and F are made up of two units that operate in parallel. The system has been repaired to perfection, and sufficient repair facilities are available as needed. All failure and repair rates have been assumed to be constant. The failure and repair rates of units are assumed to be constant, and transient probability considerations under the Markov-process are useful for drawing the system's transient state diagram in steady state.RPGT is used to model system parameters and uses Laplace transformations to estimate mean sojourn times of various stage expressions. Drawing tables and graphs, followed by talks, are used to show the effect of different units on system performance characteristics while keeping their failure or repair rates constant. The essential data for estimating various failure and repair rates is gathered with the assistance of the paint manufacturing plant's maintenance workers in Jaipur, India.

2. Assumptions and notations

- Failure and repair rates are constant.
- A, B, D, E, F, and Q are used for working state.
- A, b, d, e, and f are used for failed state.
- $\bar{a}$: It is used for standby mode.

- x_i and y_i ($1 \leq i \leq 5$): Indicates the failure/repair rates of subunits
- S_i ($1 \leq i \leq 10$: Indicates States

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

S_1 = ABDEF, S_2 = aBDEF, S_3 = ABDeF, S_4 = ABDEf,
S_5 = AbDEF, S_6 = ABdEF, S_7 = a′BDeF, S_8 = a′BDEf,
S_9 = a′bDEf, S_{10} = a′BdEF

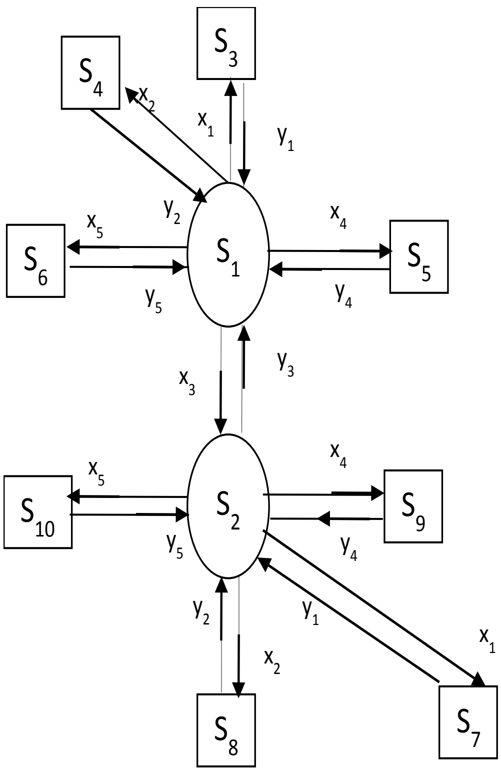

Fig:1 Transition Diagram

2.1 System Description

A paint manufacturing plant involves of subsequentunit'sMixer (A), grinding mill (B), dilution (D), Labeling (E), and filling machine (F). Units 'A' and 'B' have sub-units in series, henceforth are exposed to major disappointments when everyone of their sub-unit fail. Units 'E' and 'F' have sub-unit in parallel in the herb hence are exposed to minor and major disappointments x_1, x_2 are continuousdisappointment rates of sub structure 'E' and 'F' individually x_3, x_4, x_5 are constantdisappointment rates of sub units A, B & D individually, y_1, y_2, y_3, y_4, y_5 are constant repair rates of units E, F, A, B & D individually.

A single repairman is accessible 24 hours a day, seven days a week. If the server is available, repair of a failed unit begins immediately; otherwise, the failed unit joins the list of units waiting for repair whenever the filter system foils.

Originally the framework is in filled capacity functioning state S_1 [ABDEF], in which all the sub-units are operational from state on disappointment of everyone units E, F, A, B, D at rates m_1, m_2, m_3, m_4, $m_5$organization joins the operational state S_2 [aBDEF] failed state S_3 [ABDeF], S_4 [ABDEf], S_5 [AbDEF], S_6 [ABdEF] frameworkreturns the states S_1 while in occupied state S_2 where the dough is managed automatically of additional any of the units E, F, B, D at disappointment rates m_1, m_2, m_4, $m_5$individuallyframeworkreturns the states S_7 [a´BdEF], S_8 [a´BDEf], S_9 [a´bDEF], S_{10} [a´BdEF]. On repair of higher priority sub-units the scheme again returns the state S_2 where pre-emptive restart repair of failed unit ‘a’ is agreed out.

Table 1: Transition Probabilities

$q_{i,j}(t)$	$P_{ij} = q^*_{i,j}(0)$
$q_{1,2}(t) = x_3 e^{-(x_1+x_2+x_3+x_4+x_5)t}$	$p_{1,2} = x_3/(x_1+x_2+x_3+x_4+x_5)$
$q_{1,3}(t) = x_1 e^{-(x_1+x_2+x_3+x_4+x_5)t}$	$p_{1,3} = x_1/(x_1+x_2+x_3+x_4+x_5)$
$q_{1,4}(t) = x_2 e^{-(x_1+x_2+x_3+x_4+x_5)t}$	$p_{1,4} = x_2/(x_1+x_2+x_3+x_4+x_5)$
$q_{1,5}(t) = x_4 e^{-(x_1+x_2+x_3+x_4+x_5)t}$	$p_{1,5} = x_4/(x_1+x_2+x_3+x_4+x_5)$
$q_{1,6}(t) = x_5 e^{-(x_1+x_2+x_3+x_4+x_5)t}$	$p_{1,6} = x_4/(x_1+x_2+x_3+x_4+x_5)$
$q_{2,1}(t) = h_3 e^{-(x_1+x_2+x_4+x_5+y_3)t}$	$p_{2,1} = y_3/(x_1+x_2+x_4+x_5+y_3)$
$q_{2,7}(t) = x_1 e^{-(x_1+x_2+x_4+x_5+y_3)t}$	$p_{2,7} = x_1/(x_1+x_2+x_4+x_5+y_3)$
$q_{2,8}(t) = x_2 e^{-(x_1+x_2+x_4+x_5+y_3)t}$	$p_{2,8} = x_2/(x_1+x_2+x_4+x_5+y_3)$
$q_{2,9}(t) = x_4 e^{-(x_1+x_2+x_4+x_5+y_3)t}$	$p_{2,9} = x_4/(x_1+x_2+x_4+x_5+y_3)$
$q_{2,10}(t) = x_5 e^{-(x_1+x_2+x_4+x_5+y_3)t}$	$p_{2,10} = x_5/(x_1+x_2+x_4+x_5+y_3)$
$q_{3,1} = y_1 e^{-y_1 t}$	$p_{3,1} = 1$
$q_{4,1} = y_2 e^{-y_2 t}$	$p_{4,1} = 1$

$q_{5,1}= y_4 e^{-y_4 t}$	$p_{5,1}= 1$
$q_{6,1}= h_5 e^{-h_5 t}$	$p_{6,1}= 1$
$q_{7,2}= h_1 e^{-h_1 t}$	$p_{7,2}= 1$
$q_{8,2}= h_2 e^{-h_2 t}$	$p_{8,2}= 1$
$q_{9,2}= h_4 e^{-h_4 t}$	$p_{9,2}= 1$
$q_{10,2}= h_5 e^{-h_5 t}$	$p_{10,2}= 1$

Table 2: Mean Sojourn Times

$R_i(t)$	$\mu_i=R_i^*(0)$
$R_1(t)= e^{-(x_1+x_2+x_3+x_4+x_5)t}$	$\mu_1= 1/(x_1+x_2+x_3+x_4+x_5)$
$R_2(t)= e^{-(x_1+x_2+x_4+x_5+y_3)t}$	$\mu_2= 1/(x_1+x_2+x_4+x_5+y_3)$
$R_3(t)= e^{-y_1 t}$	$\mu_3= 1/y_1$
$R_4(t)= e^{-y_2 t}$	$\mu_4= 1/y_2$
$R_5(t)= e^{-y_4 t}$	$\mu_5= 1/y_4$
$R_6(t)= e^{-y_5 t}$	$\mu_6= 1/y_5$
$R_7(t)= e^{-y_1 t}$	$\mu_7= 1/y_1$
$R_8(t)= e^{-y_2 t}$	$\mu_8= 1/y_2$
$R_9(t)= e^{-y_4 t}$	$\mu_9= 1/y_4$
$R_{10}(t)= e^{-y_5 t}$	$\mu_{10}= 1/y_5$

3. Evaluation of Path Probabilities:

Applying RPGT the transition path probability factors of all the reachable states from the base state 'ξ' = '1' are:

$L_{1,1} = 1$

$L_{1,2}$ = (1,2)/[{1-(2,7,2)}{1-(2,8,2)}{1-(2,9,2)}{1-(2,10,2)}]

$= p_{1,2}/\{(1-p_{2,7}p_{7,2})(1-p_{2,8}p_{8,2})(1-p_{2,9}p_{9,2})(1-p_{2,10}p_{10,2})\}$

$L_{1,3}$ = (1,3)

= $p_{1,3}$

$L_{1,4}$ = (1,4)

= $p_{1,4}$

$L_{1,5}$ = (1,5)

= $p_{1,5}$

$L_{1,6}$ = (1,6)

= $p_{1,6}$

$L_{1,7}$ = (1,2,7)/[{1-(2,7,2)}{1-(2,8,2)}{1-(2,9,2)}{1-(2,10,2)}]

= $p_{1,2}p_{2,7}/\{(1-p_{2,7}p_{7,2})(1-p_{2,8}p_{8,2})(1-p_{2,9}p_{9,2})(1-p_{2,10}p_{10,2})\}$

$L_{1,8}$ = (1,2,8)/[{1-(2,7,2)}{1-(2,8,2)}{1-(2,9,2)}{1-(2,10,2)}]

= $p_{1,2}p_{2,8}/\{(1-p_{2,7}p_{7,2})(1-p_{2,8}p_{8,2})(1-p_{2,9}p_{9,2})(1-p_{2,10}p_{10,2})\}$

$L_{1,9}$ = (1,2,9)/[{1-(2,7,2)}{1-(2,8,2)}{1-(2,9,2)}{1-(2,10,2)}]

= $p_{1,2}p_{2,9}/\{(1-p_{2,7}p_{7,2})(1-p_{2,8}p_{8,2})(1-p_{2,9}p_{9,2})(1-p_{2,10}p_{10,2})\}$

$L_{1,10}$ = (1,2,10)/[{1-(2,7,2)}{1-(2,8,2)}{1-(2,9,2)}{1-(2,10,2)}]

= $p_{1,2}p_{2,10}/\{(1-p_{2,7}p_{7,2})(1-p_{2,8}p_{8,2})(1-p_{2,9}p_{9,2})(1-p_{2,10}p_{10,2})\}$

4. Modeling system parameters

Mean time to system failure (T_0): The reformative un-failed states to which the framework can transit(primary state '1'), previously entering any unsuccessful state are: 'i' = 1, charming 'ξ' = '1'

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

Availability of the System(A_0): The reformative states at which theframework is accessible are 'j' = 1,2, and 'ξ' = '1'

$A_0 = \left[\sum_j L_{\xi,j}, f_j, \mu_j\right] \div \left[\sum_i L_{\xi,i}, f_j, \mu_i^1\right]$

$A_0 = (L_{1,1}\mu_1 + L_{1,2}\mu_2)/D$

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

Server of busy period: The reformative states where server is busy are j = 2 ≤ i ≤10 and ξ = '1',

$B_0 = \left[\sum_j L_{\xi,j}, n_j\right] \div \left[\sum_i L_{\xi,i}, \mu_i^1\right]$

$B_0 = (L_{1,2}\mu_2 + L_{1,3}\mu_3 + L_{1,4}\mu_4 + L_{1,5}\mu_5 + L_{1,6}\mu_6 + L_{1,7}\mu_7 + L_{1,8}\mu_8 + L_{1,9}\mu_9 + L_{1,10}\mu_{10})/D$

Expected Number of Inspections by repair man: The reformative states where the repair man visits a fresh are j = 2 to 6; 'ξ' = '0'

$V_0 = \left[\sum_j L_{\xi,j}\right] \div \left[\sum_i L_{\xi,i}, \mu_i^1\right]$

$V_0 = (L_{1,2} + L_{1,3} + L_{1,4} + L_{1,5} + L_{1,6})/ D$

5. **Profit Function:** The system can be done by utilized profit function

$P_0 = D_1A_0 - (D_2B_0 + D_3V_0)$

$= D_1A_0 - D_2B_0 - D_3V_0$

Where:

$D_1 = 1200$;

$D_2 = 100$;

$D_3 = 200$

$x_i = x$ and $y_i = y$ for all ($1 \le i \le 5$):

Table 3: Profit Function

	y = 0.7	y = 0.8	y = 0.9	y = 1.
x = 0.1	1030.1	1040.2	1045.4	1052.3
x = 0.2	941.8	947.9	967.6	985.8
x = 0.3	708.7	716.5	721.7	732.3
x = 0.4	602.1	612.9	617.9	621.4

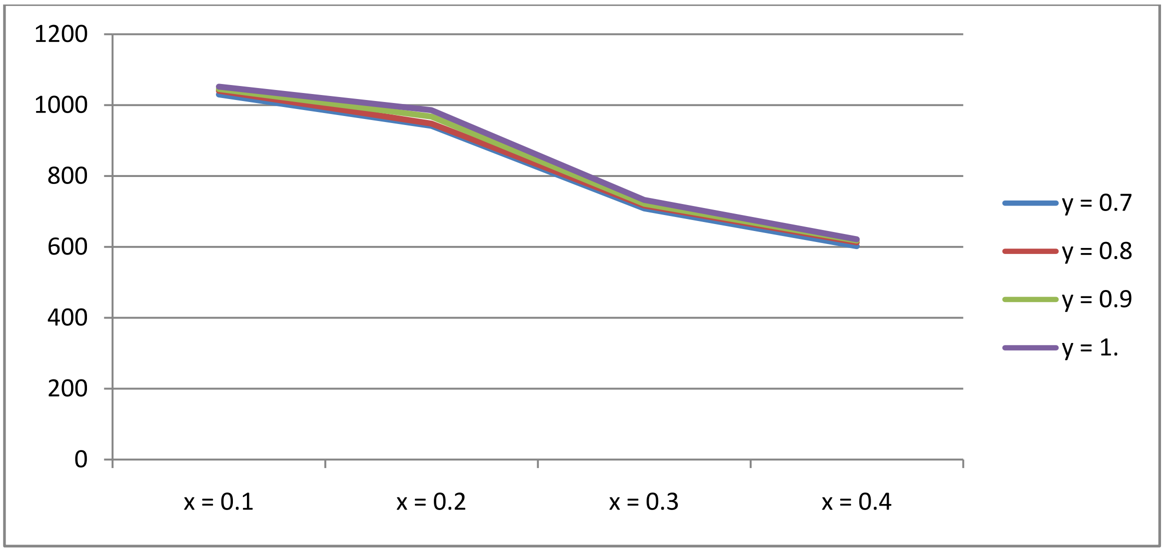

Fig. 2: Profit Function

6. Conclusion

Over all it is concluded that for optimum values of system parameters, all units should be best in quality and design with smallest possible failure rates. Improvement in repair facilities does not have more significant contribution to optimize the system parameter values. Table 3 and fig. 2 show that profit function increases with the increases in repair rates and decreases with the increases in the values of failure rates of units.

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