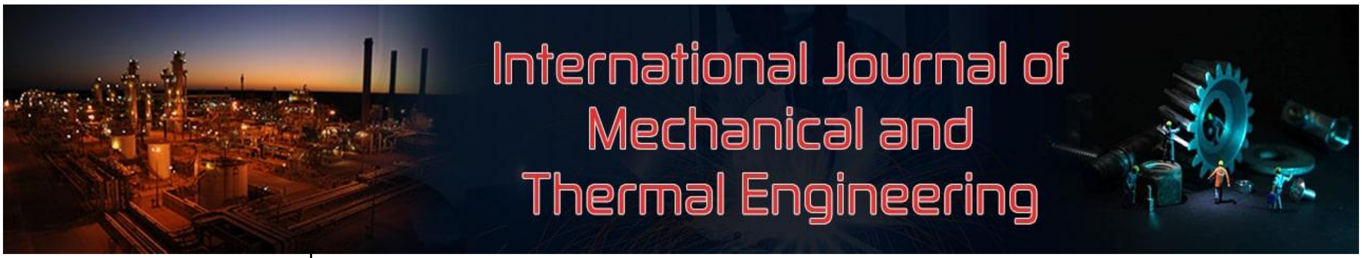

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Profit analysis of a repairable system: A case study of Raj Hans industries Pvt. Ltd. Jodhpur

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Abstract
In this paper Availability and Profit Analysis of a Repairable System using RPGT: Case Study. These online and offline units are geared by the associate structure, which also manages preventative maintenance for all categories of units and has a repair facility that is modeled for dependability performance extents. A steady state transition diagram is created using the Markov process, taking into account the constant failure and repair rates of facilities and units. Existing models and assumptions about the system can be supported or refuted by the sensitivity analysis's findings.

Keywords: Behavior analysis, availability, busy period

1. Introduction

Automation and continuous operation are causing the current trends in technological advancements in industrial systems to become smaller and more complicated. It is need of the hour to run these industries continuously for a long time; therefore, it is now required to increase reliability through standby units, particularly k-out-of-n redundancy, due to safety and its uses. The system's components should be built and set up so that, in the event of a major unit failure, a backup unit can take over and carry out the intended function whenever it is required. Consequently, before designing, it is crucial to create a vision of the system setup. In parallel configuration, the system operates less efficiently until one of its configuration's units is in good shape. In series configuration, the system fails if any one of its units fails. When the number of failed units increases, the system operates at a reduced capacity and is deemed to have failed, when the number of operating units falls below or equal to a defined value. Both configurations are independent by nature and are used to analyze reliability parameters of a simply built model. A system is referred to as a k-out-of-m: G system if it requires minimum k units to function successfully out of n units, and it is considered a failed system otherwise. These systems are widely used in industry; in this case, we have selected the G system, or system 2 out of 3, and used RPGT to assess key system parameters. Fuzzy logic is used to declare the system or subsystem to be in a failure condition. Due to the substantial contributions made by numerous reliability and operation research academics, study on redundant systems is becoming increasingly relevant. By improving system parametric values for different system types with different repair policies, these contributions have increased the effectiveness of the system. Three or two units are more than sufficient in these four/three-unit systems in terms of system functionality, profit optimization, and cost effectiveness. Examples of such systems are three-out-of-four, three-out-of-five, or four-out-of-five redundant systems. These systems have a wide range of practical applications, especially in the industrial sector. In this chapter, we've taken a two-out-of-four good redundant system and used RPGT to simulate the system parameters while accounting for unit repair and failure rates. Using the Markov approach, a transition state diagram system has been created. When a failure occurs, the standby unit is switched in and the malfunctioning unit is switched out by a single, always-available repairman. It is expected that the repairman will always be available. After repair, the defective item should function just as well as a brand-new one. Additionally, tables for potential simple pathways at various vertices are drawn. RPGT and Laplace transformations have been used to assess transition route probability and mean sojourn time expressions. The fundamental objective of the paper by Kumar *et al.* (2019) [1] focuses on the investigated examination of the washing element in the paper company consuming RPGT, while Kumar *et al*. (2017) [5] analyzed the urea compost industry for system parameters. In their 2018 study, Kumar *et al*. focused on the investigation of a bakery and an edible petroleum treatment plant. The mist group of a coal-fired thermal impact shrub was optimized by Malik *et al*. in 2022 [3]. Benefit analysis of the agribusiness harvester plants in a stable condition using RPGT was discussed by Kumari *et al*. in 2021 [4]. RPGT is used to describe system parameter expressions, and sensitivity analysis is explored in relation to fixing failure/repair rates while modifying the other. To examine the impact of different failure/repair rates on the system parameters, tables and graphs are generated and then discussed. Various path probabilities transition probabilities mean sojourn times and expressions for four reliability measures are modeled using RPGT, keeping one of the failure or repair rates of facilities units while varying the other sensitivity analysis is carried out by drawing corresponding tables and graphs followed by discussion.

2. Assumptions and Notations

- The repair procedure arises soon after a unit flops.
- Repaired unit seems to be as noble as if a novel.
- Failure/repair rates of units stay constant.
- Server facility is 24x7 hours.
- B_2, B_3, B_4, H, S: units are in good states,
- b_2, b_3, b_4, h, s: units in failed states,
- n_1, n_2, n_3, n_4, n_5: Failure rates of milk storage tanks B_2, B_3, B_4, power supply, server
- m_1, m_2, m_3, m_4, m_5: Repair rates of milk tanks B_2, B_3, B_4, power supply, server.

3. Transition Diagram Description

Accounting assumptions & notations in study Transition State Diagram of system is given in Figure 1.

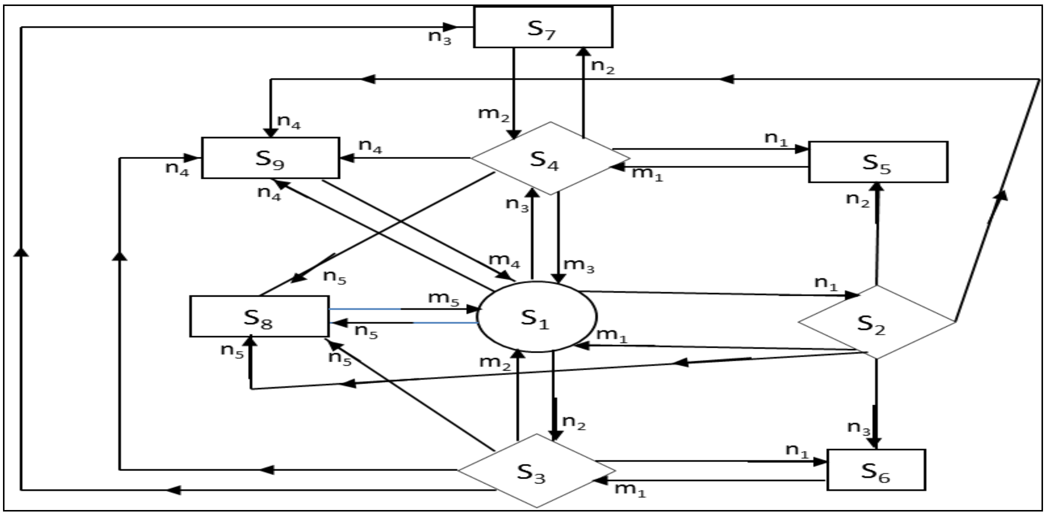

Fig 1: Transition Diagram

$S_1=B_2B_3B_4HS$,	$S_2=b_2B_3B_4HS$,	$S_3=B_2b_3B_4HS$
$S_4=B_2B_3b_4HS$,	$S_5=b_2b_3B_4HS$,	$S_6=b_2B_3b_4HS$
$S_7=B_2b_3b_4HS$,	$S_8=B_2B_3B_4Hs$,	$S_9=B_2B_3B_4hS$

4. State Transition Probabilities $q_{i,j}(t)$

$q_{1,2}(t)=n_1e^{-(n_1+n_2+n_3+n_5+n_4)t}$
$q_{1,3}(t)=n_2e^{-(n_1+n_2+n_3+n_4+n_5)t}$
$q_{1,4}(t)=n_3e^{-(n_1+n_2+n_3+n_4+n_5)t}$
$q_{1,8}(t)=n_5e^{-(n_1+n_2+n_3+n_4+n_5)t}$
$q_{1,9}(t)=n_4e^{-(n_1+n_2+n_3+n_4+n_5)t}$
$q_{2,1}(t)=m_1e^{-(m_1+n_2+n_3+n_4+n_5)t}$
$q_{2,5}(t)=n_2e^{-(m_1+n_2+n_3+n_4+n_5)t}$
$q_{2,6}(t)=n_3e^{-(m_1+n_2+n_3+n_4+n_5)t}$
$q_{2,8}(t)=n_5e^{-(m_1+n_2+n_3+n_4+n_5)t}$
$q_{2,9}(t)=n_4e^{-(m_1+n_2+n_3+n_4+n_5)t}$
$q_{3,1}(t)=m_2e^{-(m_2+n_1+n_3+n_5+n_4)t}$
$q_{3,6}(t)=n_1e^{-(m_2+n_1+n_3+n_5+n_4)t}$
$q_{3,7}(t)=n_3e^{-(m_2+n_1+n_3+n_5+n_4)t}$
$q_{3,8}(t)=n_5e^{-(m_2+n_1+n_3+n_5+n_4)t}$
$q_{3,9}(t)=n_4e^{-(m_2+n_1+n_3+n_5+n_4)t}$
$q_{4,1}(t)=m_3e^{-(m_3+n_1+n_4+n_5+n_2)t}$
$q_{4,5}(t)=n_1e^{-(m_3+n_1+n_4+n_5+n_2)t}$
$q_{4,9}(t)=n_4e^{-(m_3+n_1+n_4+n_5+n_2)t}$
$q_{4,7}(t)=n_2e^{-(m_3+n_1+n_4+n_5+n_2)t}$
$q_{4,8}(t)=n_5e^{-(m_3+n_1+n_4+n_5+n_2)t}$
$q_{5,4}=m_1e^{-m_1t}$
$q_{6,3}=m_1e^{-m_1t}$
$q_{7,4}=m_2e^{-m_2t}$
$q_{8,1}=m_5e^{-m_5t}$
$q_{9,1}=m_4e^{-m_4t}$

$P_{ij}=q^*_{i,j}(0)$

$p_{1,2}=n_1/(n_1+n_2+n_3+n_5+n_4)$
$p_{1,3}=n_2/(n_1+n_2+n_3+n_4+n_5)$
$p_{1,4}=n_3/(n_1+n_2+n_3+n_4+n_5)$
$p_{1,8}=n_5/(n_1+n_2+n_3+n_4+n_5)$
$p_{1,9}=n_4/(n_1+n_2+n_3+n_4+n_5)$
$p_{2,1}=m_1/(m_1+n_2+n_3+n_4+n_5)$
$p_{2,5}=n_2/(m_1+n_2+n_3+n_4+n_5)$
$p_{2,6}=n_3/(m_1+n_2+n_3+n_4+n_5)$
$p_{2,8}=n_5/(m_1+n_2+n_3+n_4+n_5)$
$p_{2,9}=n_4/(m_1+n_2+n_3+n_4+n_5)$
$p_{3,1}=m_2/(m_2+n_1+n_3+n_5+n_4)$
$p_{3,6}=n_1/(m_2+n_1+n_3+n_5+n_4)$
$p_{3,7}=n_3/(m_2+n_1+n_3+n_5+n_4)$
$p_{3,8}=n_5/(m_2+n_1+n_3+n_5+n_4)$
$p_{3,9}=n_4/(m_2+n_1+n_3+n_5+n_4)$
$p_{4,1}=m_3/(m_3+n_1+n_4+n_5+n_2)$
$p_{4,5}=n_1/(m_3+n_1+n_4+n_5+n_2)$
$p_{4,9}=n_4/(m_3+n_1+n_4+n_5+n_2)$
$p_{4,7}=n_2/(m_3+n_1+n_4+n_5+n_2)$
$p_{4,8}=n_5/(m_3+n_1+n_4+n_5+n_2)$

$p_{5,4}=1$
$p_{6,3}=1$
$p_{7,4}=1$
$p_{8,1}=1$
$p_{9,1}=1$

5. Mean Sojourn Times $R_i(t)$
$R1(t)=e-(n1+n2+n3+n4+n5)\ t$
$R2(t)=e-(m1+n2+n3+n4+n5)\ t$
$R3(t)=e-(m2+n1+n3+n5+n4)\ t$
$R4(t)=e-(m3+n1+n4+n5+n2)\ t$
$R_5(t)=e^{-m}1t$
$R_6(t)=e^{-m}1t$
$R_7(t)=e^{-m}2t$
$R_8(t)=e^{-m}5t$
$R_9(t)=e^{-m}4t$

$\mu_i=R_i^*(0)$
$\mu_1 = 1/(n_1+n_2+n_3+n_4+n_5)$
$\mu_2= 1/(m_1+n_2+n_3+n_4+n_5)$
$\mu_3= 1/(m_2+n_1+n_3+n_5+n_4)$
$\mu_4= 1/(m_3+n_1+n_4+n_5+n_2)$
$\mu_5=1/m_1$
$\mu_6= 1/m_1$
$\mu_7 = 1/m_2$
$\mu_8 = 1/m_5$
$\mu_9=1/m_4$

6. Evaluation of Transition Path Probabilities:
$V_{1,1} = 1$
$V_{1,2}=p_{1,2}$
$V_{1,3}$= [p1,3/p1,2p2,6p6,3(1-p3,6p6,3)]/(1-p3,6p6,3)
$V_{1,4}$= Continues

7. Modeling system parameters
MTSF (T_0): Un-failed state to which system transits (from initial state1'), before visiting failed state are: j'=1, 2, 3, 4 taking ξ' = 1.

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

$T_0=(V_{1,1}\mu_1+V_{1,2}\mu_2+V_{1,3}\mu_3+V_{1,4}\mu_4+V_{1,5}\mu_5+V_{1,6}\mu_6+V_{1,7}\mu_7)$ / $\{1- p_{1,2}p_{2,1}\} + [(p_{1,3}p_{3,1})$ / $\{1- p_{3,6}p_{6,3}\}] + [(p_{1,2}p_{2,6}\ p_{6,3}p_{3,1})$ / $\{1- p_{6,3}p_{3,6}\}\ \{1- p_{3,6}p_{6,3}\}] + [(p_{1,3}p_{3,7}\ p_{7,4}p_{4,1})$ / $\{1- p_{3,6}p_{6,3}\}\ \{1-p_{4,7}p_{7,4}\}\ \{1-p_{7,4}p_{4,7}\}\ \{1-p_{4,5}p_{5,4}\}] + [(p_{1,4}p_{4,1})$ / $\{1-p_{4,7}p_{7,4}\}\ \{1-p_{4,5}p_{5,4}\}] + [(p_{1,2}p_{2,5}\ p_{5,4}p_{4,1})$ / $\{1- p_{5,4}p_{4,5}\}\ \{1- p_{4,5}p_{5,4}\}\ \{1-p_{4,7}p_{7,4}\}]$

Availability of System (A_0): The states where system is available are j'=1, 2, 3, 4 taking = 1 'total time for which system is available is

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

$A_0 = [\sum_j V_\xi f_j] \div [\sum_i V_{\xi,i} f_j \mu^1]$

Busy Period of Server (B_0): The states where server is busy are S_i where $2 \le i \le 9$, taking $\xi = 1$ total time for which, the server remains busy is

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

$B_0 = [\sum_j V_\xi n] \div [\sum_i V_{\xi,i}\mu^1]$

Expected Fractional Number of Inspections by the repair man (V_0): The states where the repairman does visit's a fresh are S_i, where i = 2, 3, 4, 8, 9 taking ξ' = 1', number of visit by repairman is

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

$V_0=[\sum_j V_\xi] \div [\sum_i V_{\xi,}\mu^1]$

8. Particular Cases
Profit Function (P_0)
The system can be done by utilized PF

$P_0 = D_1A_0 - (D_2B_0 + D_3V_0) = D_1A_0 - D_2B_0 - D_3V_0,$
Taking $D_1 = 1300$; $D_2 = 100$; $D_3 = 200$,
we have

Table 1: Profit Function

P_0	m = 0.50	m = 0.60	m = 0.70
n = 0.10	29728	29864	30000
n = 0.20	27846	26799	28352
n = 0.30	26484	26750	27029

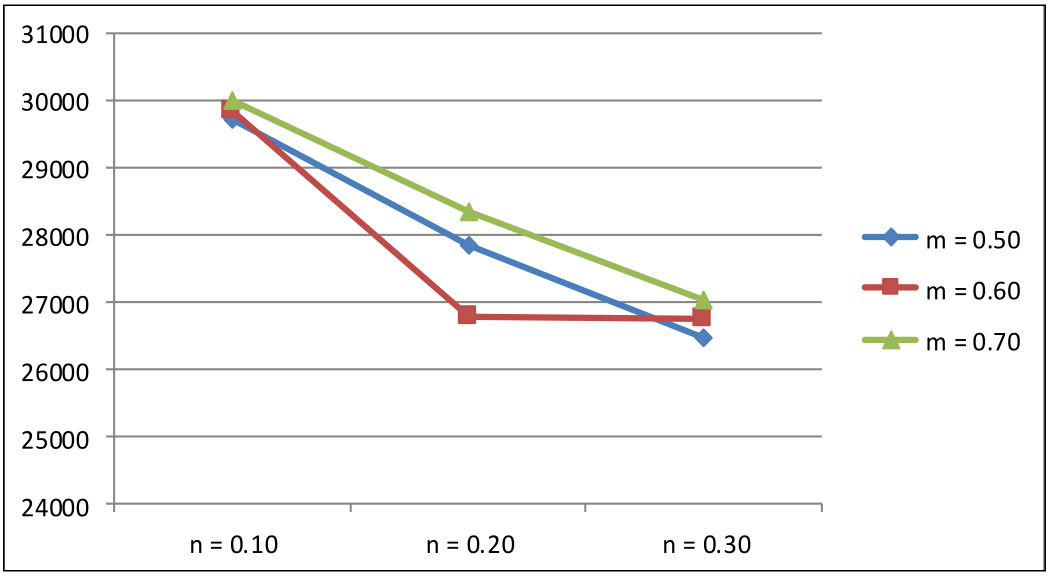

Fig 2: Profit Function

9. Conclusion

The results of the profit analysis can be used to validate or challenge existing models and assumptions about the system. For example, the analysis could show that a certain parameter has a much greater impact on system performance than previously thought. It can help optimize maintenance strategies, improve system design, and reduce downtime and maintenance costs. For example, profit increases with an increase in RR and decreases with an increase in estimations of unit FR, as shown in Figure 2 and Table 1. Therefore, for the best PF estimations, repairmen should be as efficient as is reasonably practicable in terms of repairs. This is because the PF is inversely PP to disappointment/FR.

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