Expected Number Of Server's Visits Analysis Of Paint Manufacturing Plant In Rohtak District

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ABSTRACT

This paper presents a detailed quantitative analysis of maintenance interventions in a paint manufacturing plant located in Rohtak District, Haryana, focusing on the expected number of server (repair personnel) visits. Utilizing the Regenerative Point Graphical Technique (RPGT), the study models the plant as a series system comprising four critical subsystems: Mixer, Grinding and Dilution, Labeling Machine, and Filling Machine. Analytical expressions are derived for key reliability measures, with particular emphasis on the expected frequency of repair visits under varying failure and repair rates. The findings deliver actionable insights for plant managers, supporting the optimization of preventive maintenance strategies and the enhancement of system reliability and operational efficiency in industrial environments.

Keywords:- Availability, Paint Manufacturing, Reliability Analysis, Steady State

1. INTRODUCTION:

The pursuit of operational excellence is a defining challenge for modern process industries, where equipment reliability, maintenance efficiency, and production continuity are critical drivers of business success. In paint manufacturing plants, where downtime can lead to significant production losses and customer dissatisfaction, a robust maintenance strategy is indispensable. The reliability and maintainability of each subsystem—from mixing to final filling—determine the overall throughput and profitability of the enterprise. In this context, understanding the expected number of maintenance server visits is vital for both operational planning and resource allocation. Frequent repair interventions may signal underlying design or operational weaknesses, while infrequent visits may reflect either robust equipment or potential gaps in failure detection. The quantification and analysis of these server visits provide a practical metric for evaluating the effectiveness of maintenance policies and predicting future workload. Agrawal et al. (2021) highlighted the role of advanced reliability modeling, including the use of RPGT, in performance analysis of water treatment plants, emphasizing how such techniques inform maintenance scheduling and operational efficiency. Devi (2019) explored the use of base state analysis to determine mean time to system failure (MTSF) and system availability in multi-unit standby systems, demonstrating the applicability of stochastic modeling in predicting plant reliability. Garg and Garg (2022) examined the impact of preventive maintenance and neglected faults in briquette machines, finding that systematic reliability analysis leads to improved performance and reduced risk of unplanned failures. Malik and Goel (2016) presented a cost-benefit and availability analysis for two-module systems, establishing that regular maintenance and reliability-centered planning can significantly enhance system efficiency. Ritikesh and Goel

(2015) focused on degradation and post-repair availability in single-unit systems, utilizing RPGT to model and analyze reliability under practical repair scenarios. Research on redundancy allocation and multi-level system design, such as that by Torrado and Jorge (2021), demonstrates that redundancy and optimal resource allocation are critical to sustaining high availability in modular systems. Zhang and Zeng (2016) further advanced maintenance modeling by integrating non-identical units and extended decision support methods, enabling more precise assessment of maintenance strategies and expected repair interventions. This study applies the Regenerative Point Graphical Technique (RPGT), a sophisticated modeling approach rooted in Markov process theory, to the reliability analysis of a real-world paint manufacturing plant in Rohtak District, Haryana. The plant is represented as a series system of four subsystems—Mixer, Grinding and Dilution, Labeling Machine, and Filling Machine—each essential for uninterrupted production. The model assumes constant failure and repair rates for each subsystem, enabling clear mathematical formulation and tractable solutions. A comprehensive state transition diagram is constructed to capture all possible operational, degraded, and failed plant states. With RPGT, closed-form expressions are derived for critical system parameters, specifically focusing on the expected number of repair visits under different operational scenarios. The analysis incorporates both steady-state conditions and sensitivity to changes in system parameters.

2. SYSTEM DESCRIPTION

The paint manufacturing plant operates as a series system comprising four essential subsystems: Mixer, Grinding and Dilution, Labeling Machine, and Filling Machine. Each subsystem is responsible for a critical stage of production—from blending raw materials to refining paint texture, applying regulatory labels, and accurately filling containers. Mechanical or operational failures in any unit can disrupt the entire process, leading to downtime and quality issues. Routine maintenance, calibration, and timely repairs are vital across all subsystems to sustain consistent productivity and uphold product standards. Thus, reliability analysis and preventive maintenance are crucial for ensuring the plant's smooth operation and overall efficiency.

3. ASSUMPTIONS AND NOTATIONS

- A single repairman is available 24*7.
- Repaired unit is new.
- A/a: Unit 'A' in good / failed state.
- B/ (B)//b: Redundant unit in operative/ standby / failed state.

4. TRANSITION DIAGRAM OF THE SYSTEM

Following the above assumptions and notations, the transition diagram of the system is as shown in Figure 1. The system can be in any of the following states with respect to the above symbol.
S_2 = A(B)CD; S_3= a(B)Cd; S_4= a(B)CD; S_5 = A(B)cD; S_6 =A(B)Cd; S_7 = a(B)cD; S_8 = AbCd; S_9= abCD; S_{10} = AbCD; S_{11} = AbcD

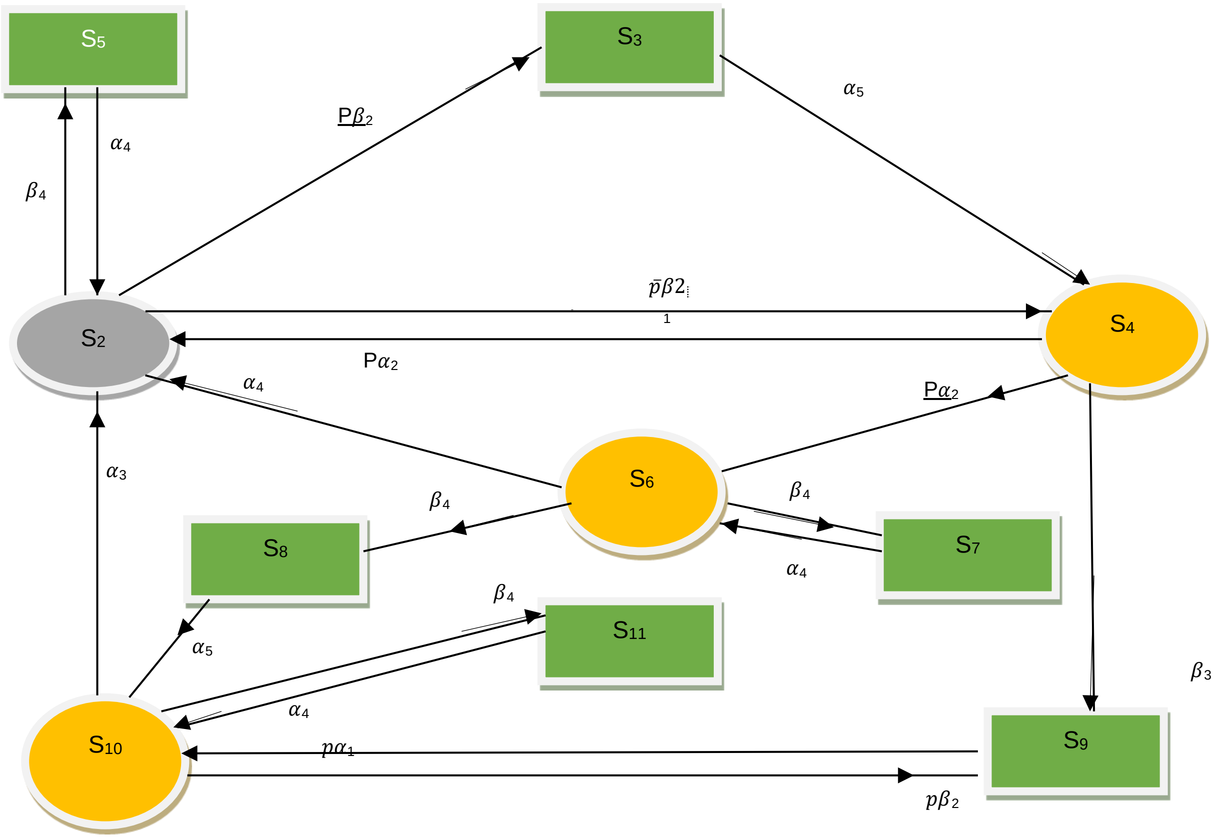

Figure 1: TRANSITION DIAGRAM OF THE SYSTEM

5. TRANSITION PROBABILITY FACTORS:

The mean time to system failure and all the key parameters of the system (under steady state conditions) are evaluated by using Regenerative Point Graphical Technique (RPGT) and using '2' as the base state of the system as under: -

$V_{2,2}$= 1 (Verified)

$V_{2,3}$= (2, 3) = $p_{2,3}$

$V_{2,4}$= ……Continue

6. EVALUATION OF PARAMETERS:

Expected number of server's visits (V_0): The regenerative state to which server visits a fresh are j = 3, 4, 5 and the regenerative states are j = 2 to 11. Therefore no expected no. of server's visit for 'ξ' = '2' is given by

$$V_0 = \left[\sum_{j,s_r}\left\{\frac{\left\{pr\left(\xi \xrightarrow{s_r} j\right)\right\}}{\prod_{k_1\neq\xi}\left\{1-V_{k_1,k_1}\right\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\left\{pr\left(\xi \xrightarrow{s_r} i\right)\right\}\mu_i^1}{\prod_{k_2\neq\xi}\left(1-V_{k_2,k_2}\right)}\right\}\right]$$

$V_0 = (V_{2,3} + V_{2,4} + V_{2,5})/D$

$D = [V_{2,2}\mu_2 + V_{2,3}\mu_3 + V_{2,4}\mu_4 + V_{2,5}\mu_5 + V_{2,6}\mu_6 + V_{2,7}\mu_7 + V_{2,8}\mu_8 + V_{2,9}\mu_9 + V_{2,10}\mu_{10} + V_{2,11}\mu_{11}]$

7. PARTICULAR CASES: -

For $\beta_i = \beta$; $2 \le i \le 4$; $\alpha_i = \alpha$; $2 \le i \le 5$; p = 1, $\underline{p}$ = 0,

Analytical Discussion: Behavior Analysis: Fix; $\alpha = \alpha_i$; $\beta = \beta_i$

Table 1: Expected Number of server's visits (V_0)

β \ α	0.55	0.65	0.75
0.15	0.098	0.090	0.083
0.25	0.114	0.100	0.089
0.35	0.117	0.107	0.103

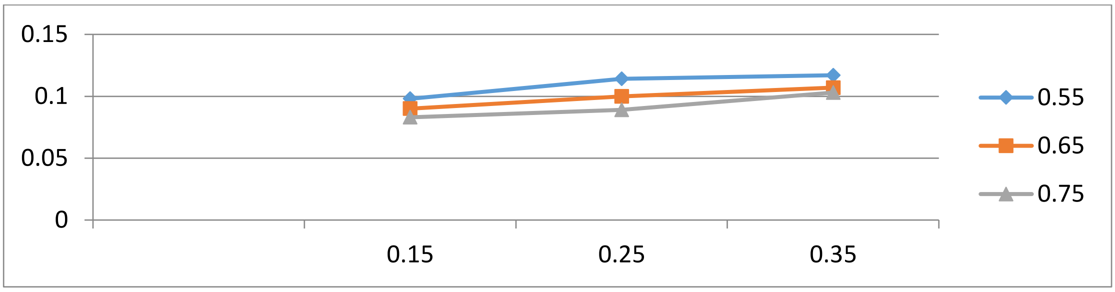

Fig. 2: Expected Number of Server's Visits

Table 1 and Figure 2 provide a quantitative view of the expected number of visits made by the maintenance server (repair personnel) to attend to failures within the paint manufacturing plant located in Rohtak, Haryana. A closer inspection of the data reveals that as the failure rate of the plant's machinery increases, the expected number of repair visits also rises. For instance, when the failure rate is minimal (0.15), the expected number of visits per unit time remains low, with figures decreasing from 0.098 to 0.083 as the repair rate increases from 0.55 to 0.75. However, as the failure rate is elevated to 0.25 and 0.35, the frequency of required repair interventions rises as well. At the highest failure rate examined (0.35), the expected number of server's visits peaks at 0.117 for the lowest repair rate and remains comparatively elevated even as repair efficiency improves.

8. CONCLUSION:

This study provides a comprehensive analysis of the expected number of maintenance server visits in a paint manufacturing plant in Rohtak District using the Regenerative Point Graphical Technique (RPGT). The findings reveal a direct relationship between subsystem failure rates and the frequency of repair interventions: as equipment becomes less reliable, the expected maintenance workload increases. Conversely, improving repair rates leads to a reduction in the number of required server visits, though the effect tapers at higher failure rates. These results offer plant managers actionable insights for optimizing preventive maintenance schedules and resource allocation. By quantifying and understanding maintenance demands, the plant can enhance its reliability, reduce downtime, and improve overall operational efficiency. The research demonstrates the value of integrating reliability analysis into decision-making processes, ensuring sustained productivity and cost-effectiveness in industrial environments.

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