OPTIMIZATION OF THE TWO UNIT SYSTEMS WITH DEGRADATION AND PREVENTIVE MAINTENANCE IN ONE UNIT USING DEEP LEARNING ALGORITHMS

Shakuntla Singla[1], Komalpreet Kaur[2*]

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[1,2] Department of Mathematics and Humanities, MMEC, Maharishi Markandeshwar
(Deemed to be University), Mullana, Ambala, India

[1]shakus25@gmail.com,[2*]komalsandha659@gmail.com[2]

Abstract

This study presents a comprehensive behavioral examination of a two-unit organization integrating preventive maintenance strategies and the introduction of degradation in single unit following complete failure. The research explores the intricate dynamics influencing the system's reliability, availability, and performance. The impact of preventive maintenance on reducing unexpected failures and enhancing overall system robustness is investigated, alongside the added complexity introduced by degradation modeling using three methods ADAM, SGD and RMS Prop. The interplay between preventive maintenance and degradation is analyzed, emphasizing the critical role of optimization in achieving effective system performance. Trade-off analysis reveals the delicate balance between maintenance costs and savings from avoiding failures, guiding decision-makers in determining the most cost-effective strategies. Sensitivity analysis identifies key parameters influencing system behavior, aiding in informed decision-making and robust system design. Consideration of life-cycle costs provides a holistic economic perspective, evaluating both short-term and long-term implications of maintenance and operational choices. This model is train in three methods (ADAM, SGD, and RMS Prop), In MTSFof Adam is better than other two methods. In Expected Number of Inspections by repair man of SGD is better than other two methods. In Recall (Busy Period) of Adam is better than other two methods. In Precision (Availability of the System) of RMS Prop is better than other two method.

Keywords: Optimization, RPGT, Deep learning, Adam, SGD, RMS prop

I. Introduction

Plants and all of its industries is not one unique unit. Different processing techniques and businesses assemble many units. This chapter analyses a system made up of two units that incur degradation upon complete failure and that only receive preventive maintenance on one unit prior to a partial failure. A variety of devices coupled in series, parallel, or mixed mode make up a system. The failure of each individual unit determines the system's overall failure. Preventive maintenance is applied in many process industries, including those where a two-unit system is common. In these sectors, one unit is more critical than the other and needs greater care. The system as a whole fails if that one unit malfunctions.

Agrawal et al. [1] this research study uses the RPGT to analyzed water treatment RO plant's profitability under particular structure parameter settings. Chen and Hsieh [3] in this research, we transform the two-dimensional uninterrupted - k - out - of - n: F structure by using fake perfect components. The effectiveness of the strategy put forth is demonstrated by numerical results. A sensitivity study of a urea fertiliser production system with multiple sub-systems of different types is shown in Garg et al. [2]. System managers, exercise supervisors, engineers, and trustworthiness analysts in the industrial sector can all benefit from the analysis and findings presented in this paper. Kumar [4] the author of this study has examined a system known as the linear consecutive 2-ot-of-4: F structure, which has a unique kind of k-out-of-n redundancy. Sensitivity analysis is also used to determine the system's critical units. Raghav et al. [5] studied the convenience and cost function of a continuous functioning series-parallel classification in a fixed time environment are assessed in this study. A strong statistical test is castoff to associate the outcomes and the PSO comes out on top. Singla et al. [6] this research uses supplementary variable technique to calculate the dependability of a four-unit Polytube manufacturing factory. Singla et al. [7] this study presents a scientific model based on the Chapman Kolmogorov approach for determining availability under limited capacity, with the aid of transition diagrams linked to different conceivable combinations of probability. The analysis found that the most significant influence on the overall system availability of some subsystems is the subsystem extruder. Using RPGT, Singla et al. [8] examined the Rice Plant Cost Optimization and Mathematical Modeling. The mathematical modelling and optimisation of the feed plant's system parameters using machine learning technology was examined by Singla et al. [9].Taking into account the significance of each unit in the structure

Therefore, in this study, we require analyzed a two-unit structure under PM in the main unit previously complete disappointment and degradation after comprehensive failure, bearing in mind the relevance of each individual unit in the overall system. Every time the unit deteriorates more, there will come a point at which it can no longer be repaired or it might not be wise to do so because doing so would increase maintenance costs or cause production to be lost. The quality of products may not be up to the mark there may be difficulty in selling the products in the market, resulting into a loss in market share and repeat order of product. Keeping all these in mind, an individual unit needs more care hence preventive maintenance as per schedule or when the need arises is carried out by a repairman or server. A system transition diagram is created by accounting for different scenarios and path probabilities. Since the failure rate of most units is exponential, the failure rate of an individual is also exponential. The unit gets replaced with a new one if the server detects that it cannot be repaired. To ascertain whether the unit is operating at full capacity or at a reduced capacity, fuzzy logic may be employed.

II. Assumptions, Notations and Transformation Diagram

- The system is discussed for long run means for time is infinite
- Preventive Maintenance is available for main unit A only not in other units.
- The backup unit is activated as soon as the primary unit fails, provided that the switch is operational and unbreakable.
- The main unit is switched on as online if the standby unit is online while the main unit is being serviced.
- There is only one repairman facility.
- Switching over to connect devices is considered perfect.
- Unit A can fail wholly and over partial failure in both ways whereas unit B can fail completely.

- The failure rate from A to $\bar{A}$ is λ_1, $\bar{A}$ to a is λ_2, $\bar{A}_1$ to a_1 is λ_3 and A to a is λ.
- The failure rates of unit B from B to b is λ_4.
- The repair rates of unit $\bar{A}$ to A is w_1, a to $\bar{A}_1$ is w_2, a_1 to $\bar{A}_1$ is w_3 respectively.
- The repair rates of unit B from b to B is w_4.
- g(t) : probability density function that a new unit replaces unrepeatable unit A.
- g*(w) is Laplace Transform of probability density function g(t).
- States S_0, S_1, S_3 and S_4 are regenerative states.
- S_0=AB, S_1=$\bar{A}$B, S_2=Ab, S_3=$\bar{A}_1$B, S_4=a_1B, S_5=$\bar{A}_1$b, S_6=$\bar{A}$b, S_7=Ab

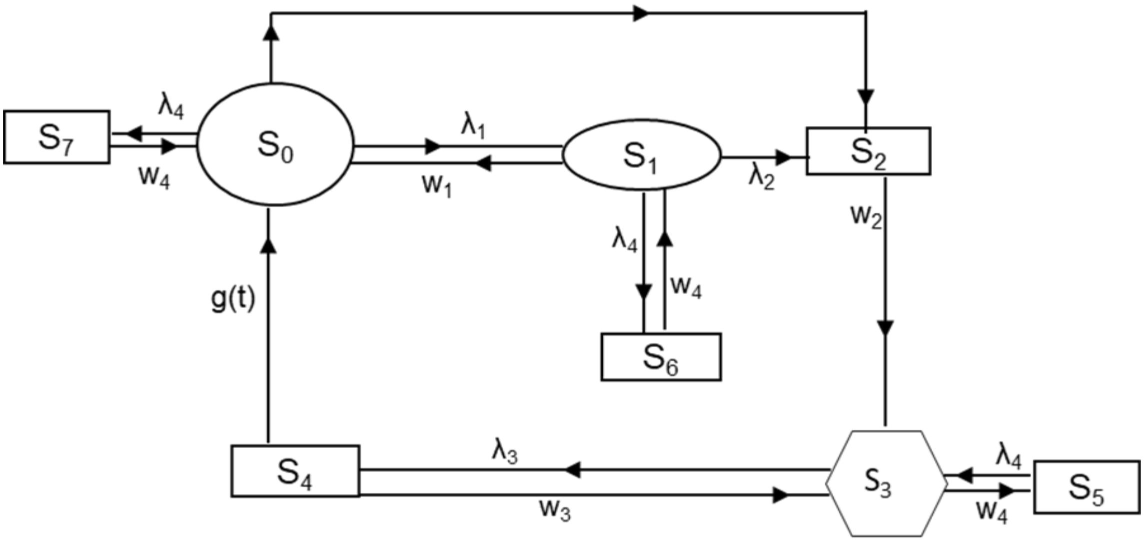

Figure 1: *Transition Diagram*

III. Description of Model

In the system under study there are two units A and B operational in full measurements initially in state S_0. Unit A need subunits in parallel so it can work in reduced capacity $\bar{A}$ when some of its subunits fail with failure rate λ_1, hence the arrangement work in reduced state S_1 in which unit B is functioning in full capacity. When unit A is in reduced state $\bar{A}$ then it is provided preventive maintenance and restored to its original state A by the repairman / server with repair rate w_1. Unit A may also fail directly from initial state at full capacity (A) to failed state a with a failure rate λ or from reduced state $\bar{A}$ to state a with failure rate $\lambda_2 > \lambda_1$ if it is not repaired within a reasonable time to state S_2, state S_2 is the state from which unit A can be repaired to its initial state and upon repair by the server it works in degraded state $\overline{A_1}$ denoted by the state S_3 while unit B is in good state. Upon failure of unit A with failure rate λ_3 to a_1 to state S_4 which on subsequent repair is restored to state S_3 each time with degraded capacity. As the repair is not perfect or it is beyond repair to bring the unit to its previous working state with repair rate w_3, there is a situation when the unit A elsewhere repair and it is substituted by a new unit with probability density function g (t). As the unit B have subunits in series so on failure of any one subunit in B it fails completely with failure rate λ_4 hence whole of the system fail from state S_0, S_1, S_3 to the state S_7, S_6, S_5 respectively in figure 1.Regarding the aforementioned symbols, the structure may be in any of the subsequent states. A Markov process, as we all know, is a stochastic process whose operational behavior is such that the probability distribution for its future development depends only on its current state, not on the process's path to get there. The Markov process is referred to as a Markov chain if the state space is discrete, that is, finite and countable infinite. The Markov chain's parameter could be continuous or discrete. The chain is referred to as a discrete parameter Markov chain if the parameter space (Index set) is likewise discrete. The duration of the system's stay in any state, as measured by the probability density function, is exponential. The next transition from state i to state j will occur because it was in state i at a specific point in time (time 't'). This transition is dependent just on i and j, not on the history of the process that led to the state i in the past. Certain issues related to queuing, reliability, and inventory theories can be tackled by utilizing Markov renewal processes. Rather than the depth of their theoretical advancements, the Markov renewal theory's significance resides mostly in their broad range of applications. Stated differently, a semi-Markov process is one that follows a Markov chain to change its state, but it deviates from the Markovian property that the future is self-determining of the past specified the existing state and has a random time interval between changes. An activity is any portion of the project which consumes time or resources and has a drainable beginning and ending the dummy activity, represented by a dashed line in project, is to confirm that all the succeeding activities can begin after the completion of all the preceding activities before the dummy. Dummy activity caries a zero time. A node or event is a instantaneous point in time, expressing the beginning and ending of activities. The nodes or events are to be numbered in ascending order. Each activity’s successor node number must be larger than its predecessor node number. The complexity of a project network depends on two factors namely the number of activities in the project and secondly on the precedence-relations among the activities. A decomposition technique is developed here to facilitate to identify to which of the above four classes, a given general project network belongs.

IV. Determination of base-state

Four, two, two four, three, one, one, and one primary circuit are located at the vertices 0, 1, 2, 3, 4, 5, 6, and 7, respectively, in the transition diagram (Figure 1). Every vertex 0 and 3 has a primary circuit linked with it. Therefore, any of them could constitute the system's initial state. As of right now, there are the fewest distinct secondary circuits along each of the principal lines that lead from vertex '0' to every vertex. The pathways leading from the vertex "0" do not contain any tertiary or higher level circuits. Therefore, there are 3 primary circuits sideways all paths as of the vertex ‘0’. And alike there are four, two and one primary, secondary and tertiary circuits individually as of the vertex ‘2’. Since, there is biggest number (four) of primary circuits at vertex ‘0’ by less integer of secondary, tertiary and higher level circuits, consequently, ‘0’ stands a base-state of model. This indicates that the principal circuits in states '0' and '3' are identical. However, there are fewer secondary and tertiary circuits in state "0”, S0 so ‘0’ base state $\xi = 0$.

Table 1: *Primary, Secondary, Tertiary Circuits w.r.t. the Simple Paths (Base-State ‘0’)*

Vertex j	$(0 \to j)$: **(P0)**	**(P1)**	**(P2)**
1	$(0 \to 1)$:{0,1}	{1,6,1}	-
2	$(0 \to 2)$:{0,2} $(0 \to 2)$:{0,1,2}	- {1,6,1}	- -
3	$(0 \to 3)$:{0,2,3} $(0 \to 3)$:{0,1,2,3}	{3,5,3}, {3,4,3} {1,6,1}, {3,5,3}, {3,4,3}	- -

4	$(0 \rightarrow 4)$:{0,2,3,4} $(0 \rightarrow 4)$:{0,1,2,3,4}	{3,5,3}, {3,4,3} {1,6,1}, {3,5,3}, {3,4,3}	- -
5	$(0 \rightarrow 5)$:{0,1,2,3,5} $(0 \rightarrow 5)$:{0,2,3,5}	{1,6,1}, {3,5,3},{3,4,3} {3,5,3}, {3,4,3}	-
6	$(0 \rightarrow 6)$:{0,1,6}	{1,6,1}	-
7	$(0 \rightarrow 7)$:{0,7}	-	-

V. TRANSITIONAL PROBABILITIES

The transitional Probabilities are the likelihoods through which the system variations its state one to another by the passage of time. In a processing industry generally, A process consists of four components: processing, inspection, transport and storage operations. Of these, only processing adds value; the others can be viewed as waste. Traditional approach has been to reduce waste through improving the activities related to the waste. To reduce inspection, we for example, adopted sampling inspection. Industry's approach is to eliminate inspection altogether by providing mistake-proofing devices. To reduce waste in transportation, we adopted usage of aids such as forklifts. Fundamental improvement in plant layout, however, will eliminate the need for transport altogether. Thus, it is confirmed that the overall state probability for every state is 1.

Table 2: *Transition Probabilities for this system*

$q_{i,j}(t)$	$P_{ij} = q^*_{i,j}(t)$
$= \lambda_1 e^{-(\quad _4)t}$ $= \lambda e^{-(\lambda \quad _4)t}$ $= \lambda_4 e^{-(\lambda \quad _4)t}$	$= \lambda_1/(\lambda+\lambda_1+\lambda_4)$ $= \lambda/(\lambda+\lambda_1+\lambda_4)$ $= \lambda/(\lambda+\lambda_1+\lambda_4)$
$= \quad ^{-(w \quad _4)t}$ $= \quad ^{-(w \quad _4)t}$ $= \quad ^{-(w \quad _4)t}$	$= w_1/(w_1+\lambda_2+\lambda_4)$ $= \lambda_2/(w_1+\lambda_2+\lambda_4)$ $= \lambda_4/(w_1+\lambda_2+\lambda_4)$
$=$	$=1$
$= \quad ^{-(\lambda \quad _4)t}$ $= \quad ^{-(\lambda \quad _4)t}$	$= \lambda_3/(\lambda_3+\lambda_4)$ $= \lambda_4/(\lambda_3+\lambda_4)$
$= g(t)e$ $= \quad \overline{g(t)}$	$= g^*w_3$ $= 1-g^*w_3$
$=$	$= w_4/w_4 =1$
$=$	$= w_4/w_4 =1$
$=$	$= w_4/w_4 =1$

Table 3: Mean Sojourn Times

$R_i(t)$	$\mu_i=R_i^*(0)$
$(t)= \quad ^{-(\lambda \quad)t}$	$\mu_0 = 1/(\lambda+\lambda_1+\lambda_4)$
$(t)= \quad ^{-(w \quad)t}$	$\mu_1 = 1/(w_1+\lambda_2+\lambda_4)$
$(t)=$	$\mu_2 = 1/w_2$
$(t)= \quad ^{-(\lambda \quad)t}$	$\mu_3 = 1/(\lambda_3+\lambda_4)$
$(t)= \quad \overline{g(t)}$	$\mu_4 = [1-g^*[(w_3)]/w_3$
$(t)=$	$\mu_5 = 1/w_4$
$(t) =$	$\mu_6 = 1/w_4$
$(t)=$	$\mu_7 = 1/w_4$

5.1 Analyzation of System Parameters

The key parameters of the coordination are appraised by defining a 'base-state' and using Regenrative Point Graphical Technique. The parameter MTSF is unwavering w.r.t. the personalize state '0' and the additional parameters are attained via exhausting base-state. The steady state path probabilities exist provided w.r.t. Base State '0' refers to
$V_{0,0} = \{(0,1,0)/[1-(1,6,1)\}+\{(0,7,0)/1\}+\{(0,1,2,3,4,0)/[1-(1,6,1)1-(3,4,3)1-(3,5,3)\}]$
$+\{(0,2,3,4,0)/[1-(3,5,3)[1-(3,4,3)\}]$
$= (p_{0,1}p_{1,0})/(1-p_{1,6}p_{6,1})+p_{0,7}p_{7,0}+(p_{0,1}p_{1,2}p_{2,3}p_{3,4}p_{4,0})/(1-p_{1,6}p_{6,1})(1-p_{3,4}\, p_{4,3})$
$(1-p_{3,5}p_{5,3})+(p_{0,2}p_{2,3}p_{3,4}p_{4,0})/[(1-p_{3,4}\, p_{4,3})(1-p_{3,5}p_{5,3})]$
$= \{\lambda_1 w_1/(w_1+\lambda_2)(\lambda_1+\lambda+\lambda_4)\}]+\{\lambda_4/(\lambda_1+\lambda+\lambda_4)\}+\{\lambda_1\lambda_2(\lambda_3+\lambda_4)/\lambda_4(w_1+\lambda_2)(\lambda_1+\lambda+\lambda_4)\}$
$g^*(w_3)+\{\lambda(\lambda_3+\lambda_4)/\lambda_4(\lambda_1+\lambda+\lambda_4)\}.g^*(w_3)= 1$
$V_{0,1} = \{p_{0,1}/1-(1,6,1)\} = \{\lambda/(\lambda_1+\lambda+\lambda_4)\}/1-\lambda_4(\lambda_2+w_1+\lambda_4) = \{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)$
$(\lambda_1+\lambda+\lambda_4)\}$
$V_{0,2} = \{(0,1,2)/1-(1,6,1)\}+(0,2) = \{p_{0,1}p_{1,2}/1-p_{1,6}p_{6,1}\}+p_{0,2}$
$= [\{\lambda_1/(\lambda_1+\lambda+\lambda_4)\lambda_2/(\lambda_2+w_1+\lambda_4)\}/1-\{\lambda_4(w_1+\lambda_2+\lambda_4)\}]$
$= \{\lambda_1\lambda_2/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}+\{\lambda_1/(\lambda_1+\lambda+\lambda_4)\}$
$= \{\lambda_1\lambda_2+\lambda(\lambda_2+w_1)\}/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}$
$V_{0,3} = \{(0,1,2,3)/1-(1,6,1)1-(3,5,3)1-(3,4,3)\}+\{(0,2,3)/1-(3,5,3)1-(3,4,3)\}$
$= \{p_{0,1}p_{1,2}\, p_{2,3}/(1-p_{1,6}p_{6,1})(1-p_{3,5}p_{5,3})(1-p_{3,4}\, p_{4,3})\}+\{p_{0,2}\, p_{2,3}/(1-p_{3,5}p_{5,3})(1-p_{3,4}\, p_{4,3})\}$
$= [\{\lambda_1/(\lambda_1+\lambda+\lambda_4)\ \lambda_2/(\lambda_2+w_1+\lambda_4)\}/\{1-\{\lambda_4/(\lambda_2+w_1+\lambda_4)1-\lambda_4/(\lambda_3+\lambda_4)1-\lambda_3/(\lambda_3+\lambda_4)]$
$+[\{\lambda/(\lambda_1+\lambda+\lambda_4)\}/\{1-\lambda_4/(\lambda_3+\lambda_4)1-\lambda_3/(\lambda_3+\lambda_4)]$
$= \{\lambda_1\lambda_2(\lambda_3+\lambda_4)^2/(\lambda_2+w_1)\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)\}+\{\lambda/(\lambda_3+\lambda_4)(\lambda_1+\lambda+\lambda_4)\}$
$= \{(\lambda_3+\lambda_4)^2(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}$
$V_{0,4} = \{(0,1,2,3,4)/[1-(1,6,1)1-(3,5,3)1-(3,4,3)\}+\{(0,2,3,4)]/[1-(3,5,3)1-(3,4,3)\}$
$= \{p_{0,1}p_{1,2}\, p_{2,3}p_{3,4}/(1-p_{1,6}p_{6,1})(1-p_{3,5}p_{5,3})(1-p_{3,4}\, p_{4,3})\}+\{p_{0,2}\, p_{2,3}p_{3,4}/(1-p_{3,5}p_{5,3})$
$(1-p_{3,4}\, p_{4,3})\}$
$= \{(\lambda_3+\lambda_4)/\lambda_4(\lambda_1+\lambda+\lambda_4)\}\{(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/(w_1+\lambda_2)\}$
$V_{0,5} = \{(0,1,2,3,5)/1-(1,6,1)1-(3,5,3)1-(3,4,3)\}+\{(0,2,3,5)/1-(3,5,3)1-(3,4,3)\}$
$= \{p_{0,1}p_{1,2}\, p_{2,3}p_{3,5}/(1-p_{1,6}p_{6,1})(1-p_{3,5}p_{5,3})(1-p_{3,4}\, p_{4,3})\}+\{p_{0,2}\, p_{2,3}p_{3,5}/(1-p_{3,5}p_{5,3})$
$(1-p_{3,4}\, p_{4,3})\}$
$= [\{\lambda_1/(\lambda_1+\lambda+\lambda_4)\ \lambda_2/(\lambda_2+w_1+\lambda_4)\ \lambda_4/(\lambda_3+\lambda_4)\}/\{1-\{\lambda_4/(w_1+\lambda_2+\lambda_4)1-\lambda_4/(\lambda_3+\lambda_4)$
$1-\lambda_3/(\lambda_3+\lambda_4)]+[\{\lambda/(\lambda_1+\lambda+\lambda_4)\}\{\lambda_4/(\lambda_3+\lambda_4)\}]/[\{1-\lambda_4/(\lambda_3+\lambda_4)1-\lambda_3/(\lambda_3+\lambda_4)]$
$= \{\lambda_1\lambda_2(\lambda_3+\lambda_4)/(w_1+\lambda_2)(\lambda_1+\lambda+\lambda_4)\lambda_3\}+\{\lambda(\lambda_3+\lambda_4)/(\lambda_1+\lambda+\lambda_4)\lambda_3\}$
$= \{(\lambda_3+\lambda_4)/\lambda_3(\lambda_1+\lambda+\lambda_4)\}\{(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/(w_1+\lambda_2)\}$
$V_{0,6} = \{(0,1,6)/1-(1,6,1)\} = p_{0,1}p_{1,6}/(-p_{1,6}\, p_{6,1}) = [\{\lambda_1/(\lambda_1+\lambda+\lambda_4)\}\{\lambda_4/(w_1+\lambda_2+\lambda_4)\}]/$
$[1-\{\lambda_4/(w_1+\lambda_2+\lambda_4)\}]$
$=\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)$
$[\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/$
$(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_2\}\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)\}/\{\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}$
$\{(1-g^*w_3)/w_3\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}$
$+\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1)\}\{1/w_4\}+\{\lambda_4/(\lambda_1+\lambda+\lambda_4)\}\{1/w_4\}]/[\{1/(\lambda_1+\lambda+\lambda_4)\}$
$+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\}/\{(\lambda_2+w_1)$
$(\lambda_1+\lambda+\lambda_4)\}\{1/w_2\}+\{(\lambda_3+\lambda_4)^2(\lambda_1\lambda_2+\lambda\lambda_2+w_1)\}/\{\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/(\lambda_3+\lambda_4)\}$
$+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)(1-g^*w_3)\}/\{\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\ w_3\}\{1-g^*(w_3)/w_3\}+$
$\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\}/\{\lambda_3(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}+\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}$
$\{1/w_4\}+\{\lambda_4/(\lambda_1+\lambda+\lambda_4)\}\{1/w_4\}]$
$V_{0,7}= p_{0,7} = \lambda_1/(\lambda_1+\lambda+\lambda_4)$

5.2 Mean Time to System Failure (MTSF) (T_0)

The reformative un-failed states toward which the structures dismiss transit, previously entering first unsuccessful state are: 'i' = 0 -7.

$$\mathrm{MTSF} = \left[\sum\nolimits_{i,sr}\left\{\frac{\left\{pr\left(\xi^{\overset{sr(sff)}{-}}\right)\right\}}{\left\{1-\ \overline{m_{1m}}\right\}}\right\}\right] \div \left[1-\sum\nolimits_{sr}\left\{\frac{\left\{pr\left(\xi^{\overset{sr(sff)}{-}}\right)\right\}}{\left\{1-\ \overline{m_{2m}}\right\}}\right\}\right] \tag{1}$$

$$\begin{aligned}
T_0 &= [(0,0)\mu_0+(0,1)\mu_1]/[1-(0,1,0)\\
&= (p_{0,0}\mu_0+p_{0,1}\mu_1)/(1-p_{0,1}p_{1,0})\\
&= [1/(\lambda_1+\lambda+\lambda_4)\}+\{\lambda_1/(\lambda_1+\lambda+\lambda_4)\}1/(\lambda_2+\lambda_4+w_1)]/[1-\{\lambda_1/(\lambda_1+\lambda+\lambda_4)\}\\
&\quad \{w_1/(w_1+\lambda_2+\lambda_4)\}]\\
&= (\lambda_2+\lambda_4+w_1+\lambda_1)/[(\lambda_1+\lambda+\lambda_4)(w_1+\lambda_2+\lambda_4)-\lambda_1 w_1]
\end{aligned}$$

5.3 Availability of the System:

The reformative states at which structure is presented exist ‘j’ = 0,1,3 and reformative states exist ‘i’ = 0 to 4 attractive ‘ξ’ = ‘0’ then the structure is available is assumed by

$$A_0= \left[\sum\nolimits_{j,sr}\left\{\frac{\{\quad (\xi^{sr\rightarrow}\ )\}}{\left\{1-\ \overline{m_{1m}}\right\}}\right\}\right] \div \left[\sum\nolimits_{i,s_r}\left\{\frac{\{\quad (\xi^{sr\rightarrow}i)\}}{\left\{1-\ \overline{m_{2m}}\right\}}\right\}\right] \tag{2}$$

$$\begin{aligned}
A_0 &= [\textstyle\sum \qquad\qquad] \div [\textstyle\sum \qquad\qquad]\\
&= V_{0,0}f_0\mu_0+V_{0,1}f_1\mu_1+V_{0,3}f_3\mu_3/(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+V_{0,5}\mu_5{}^1\\
&\quad +V_{0,6}\mu_6{}^1+V_{0,6}\mu_7{}^1)\\
&=(V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,3}\mu_3)(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+V_{0,5}\mu_5{}^1+V_{0,6}\mu_6{}^1\\
&\quad +V_{0,7}\mu_7{}^1)\\
&= [\{1/(\lambda_1+\lambda+\lambda_4)\}+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_3+\lambda_4)^2\\
&\quad (\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4(\lambda_1+\lambda+\lambda4)(\lambda_2+w_1)\}\{1/(\lambda_3+\lambda_4)\}]/\{1/(\lambda_1+\lambda+\lambda_4)\}\\
&\quad +\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+w_1)\}/\{(\lambda_2+w_1)\\
&\quad (\lambda_1+\lambda+\lambda_4)\}\{1/w_2\}+\{(\lambda_3+\lambda_4)^2(\lambda_1\lambda_2+\lambda\lambda_2+w_1)\}/\{\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/(\lambda_3+\lambda_4)\}\\
&\quad +\{\lambda_3\lambda_4(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)\}/\{\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1-g^*(w_3)/w_3\}+\{(\lambda_3+\lambda_4)\\
&\quad (\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\}/\{\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}+\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}\\
&= [\{(\lambda_2+w_1)/1\}+\lambda_1+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3\lambda_4\}]/[\{\lambda_2+w_1+\lambda_1(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/w_1\}\\
&\quad +\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)(1-g^*(w_3))/\lambda_4 w_3\}\\
&\quad +\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3 w_4\}+\{\lambda_1\lambda_4/w_4\}+\{\lambda_4(\lambda_2+w_1)/\ w4\}]
\end{aligned}$$

5.4 Proportional Busy Period of Server

The reformative states where attendant ‘j’ = 1,2,3,4 attractive ξ = ‘0’, for which the attendant remains hard is

$$B_0= \left[\sum\nolimits_{j,sr}\left\{\frac{\{\quad (\xi^{sr\rightarrow}j)\}}{\left\{1-\ \overline{m_{1m}}\right\}}\right\}\right] \div \left[\sum\nolimits_{i,s_r}\left\{\frac{\{\quad (\xi^{sr\rightarrow}i)\}}{\left\{1-\ \overline{m_{2m}}\right\}}\right\}\right] \tag{3}$$

$$\begin{aligned}
B_0 &= \left[\textstyle\sum_j V_{\xi,j}\,, n_j\right] \div [\textstyle\sum \qquad\qquad]\\
&= (V_{0,1}n_1+V_{0,2}n_2+V_{0,4}n_4+V_{0,5}n_5+V_{0,6}n_6+V_{0,7}n_7)/(V_{0,0}\ \mu^1{}_0+V_{0,1}\mu^1{}_1+V_{0,2}\mu^1{}_2\\
&\quad +V_{0,3}\mu^1{}_3+V_{0,4}\ \mu^1{}_4+V_{0,5}\mu^1{}_5+V_{0,6}\mu^1{}_6+V_{0,7}\mu^1{}_7)\\
&=(V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,4}\mu_4+V_{0,5}\mu_5+V_{0,6}\mu_6+V_{0,7}\mu_7)/(V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,3}\mu_3\\
&\qquad +V_{0,4}\ \mu_4+V_{0,5}\ \mu_5+V_{0,6}\mu_6+V_{0,7}\mu_7)\\
&= [\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\\
&\quad (\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_2\}\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)\}/\{\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\\
&\quad \{(1-g^*w_3)/w_3\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}\\
&\quad +\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1)\}\{1/w_4\}+\{\lambda_4/(\lambda_1+\lambda+\lambda_4)\}\{1/w_4\}]/[\{1/(\lambda_1+\lambda+\lambda_4)\}\\
&\quad +\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\}/\{(\lambda_2+w_1)\\
&\quad (\lambda_1+\lambda+\lambda_4)\}\{1/w_2\}+\{(\lambda_3+\lambda_4)^2(\lambda_1\lambda_2+\lambda\lambda_2+w_1)\}/\{\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/(\lambda_3+\lambda_4)\}\\
&\quad +\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)(1-g^*w_3)\}/\{\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\ w_3\}\{1-g^*(w_3)/w_3\}+\\
&\quad \{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\}/\{\lambda_3(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}+\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\\
&\quad \{1/w_4\}+\{\lambda_4/(\lambda_1+\lambda+\lambda_4)\}\{1/w_4\}]\\
&= [(\lambda_1/1)+(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/w_2\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)(1-g^*w_3)/\lambda_4 w_3\}+\{(\lambda_3+\lambda_4)\\
&\quad (\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}+\{\lambda_1\lambda_4/w_4\}+\{\lambda_1(\lambda_2+w_1)/w_4\}]/[\{(\lambda_2+w_1)+\lambda_1(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\\
&\quad /w_2\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_4 w_3\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\ (1-g^*w_3)/\lambda_3 w_4\}
\end{aligned}$$

$+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_4 w_3\}+\{\lambda_1\lambda_4/w_4\}\{\lambda_4(\lambda_2+w_1)/w_4\}]$

5.5 Expected Fractional Number of repairman's Visits (V_0)

The reformative states where overhaul man do this job j = 1 Taking 'ξ' = '0', the integer of visit by the overhaul man is specified by

$$V_0=\left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\rightarrow}j)\}}{\left\{1-\frac{\quad}{k}\right\}}\right\}\right]\div\left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\rightarrow}i)\}}{\left\{1-\frac{\quad}{k}\right\}}\right\}\right] \tag{4}$$

$V_0=[\Sigma \qquad]\div[\Sigma \qquad\qquad]$

$=(V_{0,1}+V_{0,2}+V_{0,4}+V_{0,5}+V_{0,6}+V_{0,7})/(V_{0,0}\,\mu^1{}_0+V_{0,1}\,\mu^1{}_1+V_{0,2}\,\mu^1{}_2+V_{0,3}\,\mu^1{}_3+V_{0,4}\,\mu^1{}_4$
$+V_{0,5}\,\mu^1{}_5+V_{0,6}\mu^1{}_6+V_{0,7}\mu^1{}_7)$

Taking $\mu_j{}^1=\mu_j$, using value we get

$=[\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}+\{(\lambda_3+\lambda_4)$
$(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/\lambda_4+1/\lambda_3\}+\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}$
$+\{\lambda_4/(\lambda_1+\lambda+\lambda_4)\}]/[\{1/(\lambda_1+\lambda+\lambda_4)\}+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1+\lambda_4)\}$
$+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)w_2\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_4 w_3(\lambda_1+\lambda+\lambda_4)$
$(\lambda_2+w_1)\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_4(\lambda_1+\lambda+\lambda_4)(w_1+\lambda_2)\}\{1-g^*w_3/(w_3)\}+\{(\lambda_3+\lambda_4)$
$(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}+\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}$
$+\{\lambda_4(\lambda_1+\lambda+\lambda_4)\}\{1/w_4\}]$

$=[\{\lambda_1(\lambda_2+w_1+\lambda_4)/1\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/1\}+\{(\lambda_3+\lambda_4)^2(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}$
$+\{\lambda_1\lambda_4/1\}+\lambda_4(w_1+\lambda_2)]/[(\lambda_2+w_1)+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)$
$/w_2\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3\lambda_4(1)\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)(1-g^*w_3)/\lambda_4\lambda_3\}$
$+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}+\{(\lambda_1+\lambda_4)/w_4\}+\{\lambda_4(\lambda_2+w_1)/w_4\}]$

$[\{1/(\lambda_1+\lambda+\lambda_4)\}+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_3+\lambda_4)^2$
$(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4(\lambda_1+\lambda+\lambda 4)(\lambda_2+w_1)\}\{1/(\lambda_3+\lambda_4)\}]/\{1/(\lambda_1+\lambda+\lambda_4)\}$
$+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+w_1)\}/\{(\lambda_2+w_1)$
$(\lambda_1+\lambda+\lambda_4)\}\{1/w_2\}+\{(\lambda_3+\lambda_4)^2(\lambda_1\lambda_2+\lambda\lambda_2+w_1)\}/\{\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/(\lambda_3+\lambda_4)\}$
$+\{\lambda_3\lambda_4(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)\}/\{\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1-g^*(w_3)/w_3\}+\{(\lambda_3+\lambda_4)$
$(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\}/\{\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}+\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}$
$+\{\lambda_4/(\lambda_1+\lambda+\lambda_4)\}\{1/w_4\}]$

$=[\{(\lambda_2+w_1)/1\}+\lambda_1+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3\lambda_4\}]/[\{\lambda_2+w_1+\lambda_1(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/w_1\}$
$+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)(1-g^*(w_3))/\lambda_4 w_3\}$
$+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3 w_4\}+\{\lambda_1\lambda_4/w_4\}+\{\lambda_4(\lambda_2+w_1)/\ w4\}]$

5.6 Profit Function of the System

Profit function can be used to analyses the system's profitability.

P_0 = Mean Revenue Earning Rate *Availability of system – mean rate of cost that server is busy *total busy period of the server-mean cost per visit which server charges *number of visits server called in a unit time.

$$P_0=C_1A_0-C_2B_0-C_3V_0 \tag{5}$$

$=C_1[\{(\lambda_2+w_1)/1\}+\lambda_1+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3\lambda_4\}]/[\{\lambda_2+w_1+\lambda_1(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/w_1\}+$
$\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)(1-g^*(w_3))/\lambda_4 w_3\}+\{(\lambda_3+\lambda_4)$
$(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3 w_4\}+\{\lambda_1\lambda_4/w_4\}+\{\lambda_4(\lambda_2+w_1)/\ w4\}]$

$-C_2[(\lambda_1/1)+(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/w_2\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)(1-g^*w_3)/\lambda_4 w_3\}+\{(\lambda_3+\lambda_4)$
$(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}+\{\lambda_1\lambda_4/w_4\}+\{\lambda_1(\lambda_2+w_1)/w_4\}]/[\{(\lambda_2+w_1)+\lambda_1(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)$
$/w_2\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_4 w_3\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\ (1-g^*w_3)/\lambda_3 w_4\}$
$+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_4 w_3\}+\{\lambda_1\lambda_4/w_4\}\{\lambda_4(\lambda_2+w_1)/w_4\}]$

$-C_3[\{\lambda_1(\lambda_2+w_1+\lambda_4)/1\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/1\}+\{(\lambda_3+\lambda_4)^2(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}$
$+\{\lambda_1\lambda_4/1\}+\lambda_4(w_1+\lambda_2)]/[(\lambda_2+w_1)+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)$
$/w_2\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3\lambda_4(1)\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)(1-g^*w_3)/\lambda_4\lambda_3\}$
$+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}+\{(\lambda_1+\lambda_4)/w_4\}+\{\lambda_4(\lambda_2+w_1)/w_4\}]$

$[\{1/(\lambda_1+\lambda+\lambda_4)\}+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_3+\lambda_4)^2$

$$\begin{aligned}
&(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4(\lambda_1+\lambda+\lambda4)(\lambda_2+w_1)\}\{1/(\lambda_3+\lambda_4)\}]/\{1/(\lambda_1+\lambda+\lambda_4)\}\\
&+\{\lambda_1(\lambda_2+w_1+\lambda_4)/(\lambda_2+w_1)(\lambda_1+\lambda+\lambda_4)\}\{1/(\lambda_2+w_1+\lambda_4)\}+\{(\lambda_1\lambda_2+\lambda\lambda_2+w_1)\}/\{(\lambda_2+w_1)\\
&(\lambda_1+\lambda+\lambda_4)\}\{1/w_2\}+\{(\lambda_3+\lambda_4)^2(\lambda_1\lambda_2+\lambda\lambda_2+w_1)\}/\{\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/(\lambda_3+\lambda_4)\}\\
&+\{\lambda_3\lambda_4(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)\}/\{\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1\text{-}g^*(w_3)/w_3\}+\{(\lambda_3+\lambda_4)\\
&(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)\}/\{\lambda_3\lambda_4(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}+\{\lambda_1\lambda_4/(\lambda_1+\lambda+\lambda_4)(\lambda_2+w_1)\}\{1/w_4\}\\
&+\{\lambda_4/(\lambda_1+\lambda+\lambda_4)\}\{1/w_4\}]\\
=&\,[\{(\lambda_2+w_1)/1\}+\lambda_1+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3\lambda_4\}]/[\{\lambda_2+w_1+\lambda_1(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/w_1\}\\
&+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda\lambda_2+\lambda w_1)/\lambda_3\lambda_4\}+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)(1\text{-}g^*(w_3))/\lambda_4 w_3\}\\
&+\{(\lambda_3+\lambda_4)(\lambda_1\lambda_2+\lambda w_1+\lambda\lambda_2)/\lambda_3 w_4\}+\{\lambda_1\lambda_4/w_4\}+\{\lambda_4(\lambda_2+w_1)/\ w4\}]
\end{aligned}$$

5.7 Model description of Two Unit System with Degradation and PM in Single Unit after Comprehensive Failure in Deep DLA

In the landscape of complex systems, the model describing a 2-Unit Organization with PM and Degradation in Single Unit after Comprehensive Disappointment marks a significant advancement, particularly when enriched by the sophistication of deep learning optimization techniques. This model unfolds as a comprehensive framework, weaving together intricate threads of preventive maintenance, unit degradation, and the repercussions of complete failure, all embedded within the deep learning paradigm. At its core, this model grapples with the intricacies of system reliability and performance optimization in the face of evolving challenges. The dual-unit configuration introduces a nuanced dynamic, wherein the occurrence of degradation in one unit following a complete failure introduces a layer of complexity that demands innovative solutions. The integration of deep learning optimization adds a layer of intelligence to this model, elevating it beyond traditional methodologies. Deep learning algorithms, through their aptitude to separately learn and adapt as of statistics patterns, offer a novel approach to addressing the uncertainties inherent in system behavior. By leveraging this advanced computational intelligence, the model seeks to enhance decision-making processes, predict degradation trajectories, and dynamically optimize preventive maintenance strategies. This model represents a pioneering effort to synergize the principles of reliability engineering, preventive maintenance, and artificial intelligence. It aims not only to mitigate the impact of failures but also to proactively manage system health, thereby contributing to enhanced operational efficiency and longevity. In the broader context of complex systems, where resilience and adaptability are paramount, this model stands at the forefront of innovation. Its potential applications span diverse sectors, from critical infrastructure to manufacturing processes, where optimizing system performance is not merely a goal but a necessity for sustained success. As we delve into the intricacies of this model, we uncover not just a technological advancement but a paradigm shift in how we approach the challenges of system reliability and maintenance in the era of deep learning optimization.

- Two Unit System with PM using Deep Learning Optimization: In the ever-evolving landscape of systems engineering, the model of a Two-Unit Structure through PM stands as a testament to the quest for enhanced reliability and efficiency. This sophisticated framework not only grapples with the intrinsic complexities of a dual-unit configuration but also incorporates the cutting-edge paradigm of deep learning optimization, ushering in a new era of intelligent and data-driven maintenance strategies. At its core, the Two-Unit System with Preventive Maintenance embodies a proactive approach to system health, acknowledging the inevitability of wear and degradation. This model recognizes the critical role of preventive maintenance in averting potential failures and ensuring the continuous functionality of both units. The challenge, however, lies not only in devising effective preventive maintenance schedules but in optimizing these strategies dynamically based on the evolving conditions of the system. Enter the realm of deep learning optimization – an advanced paradigm that harnesses the power of artificial intelligence to glean insights, make predictions, and adapt strategies autonomously. By integrating deep learning into the framework, this model transcends traditional approaches, allowing for a more nuanced understanding of system behavior. Deep learning algorithms, capable of learning intricate patterns from vast datasets, become the intelligent backbone of the maintenance optimization process. This model represents a departure from conventional methodologies, embracing the notion that data-driven decision-making can revolutionize the way preventive maintenance is conceptualized and implemented. The deep learning optimization component adds a layer of adaptability, allowing the system to learn from its own performance, predict potential degradation trends, and optimize preventive maintenance schedules in real-time. In an era where the reliability and longevity of systems are paramount, the Two-Unit System with Preventive Maintenance using Deep Learning Optimization emerges as a trailblazer. Its applications extend across industries where system downtime is not merely an inconvenience but a critical concern. From manufacturing plants to critical infrastructure, this model offers a glimpse into the future of maintenance strategies – one where intelligence and adaptability converge to ensure the seamless operation of complex systems. As we delve into the intricacies of this model, we embark on a journey towards a more resilient, efficient, and intelligent approach to preventive maintenance in the age of deep learning optimization.

- Behavioral Analysis of Two Unit System using Deep Learning Optimization Algorithms: Deep learning algorithms are specialized techniques designed to find the optimal parameters for Behavioral Analysis of Two Unit System during training. These algorithms aim to minimize the failure rate, allowing the Behavioral Analysis of Two Unit System to learn from the data and make accurate predictions. Here are some commonly used deep learning optimization algorithms:
- Stochastic Gradient Descent (SGD): SGD is the substance of numerous optimization algorithms. It appraises the parameters of neural network after processing each mini-batch of training data, making it computationally efficient. However, its noise can result in oscillations around the optimal solution.
- Adam (Adaptive Moment Estimation): Adam stands an adaptive culture rate optimization algorithm combining RMS prop and Momentum ideas. It dynamically adjusts the knowledge rates for both parameter built on their historic and squared gradients, if better convergence properties.
- RMS prop (Root Mean Square Propagation): RMS prop alters the scholarship rates for both parameters exclusively by in-between the wisdom rate by the square root of average of the squared gradients. It helps mitigate the diminishing learning rate problem in traditional SGD.

VI. Data Set

The dataset designed for the optimization of a Two-Unit System through PM and Degradation in Single Unit after Far-reaching Failure represents a comprehensive repository of information capturing the intricate dynamics of the system's behavior over time. This dataset serves as a vital tool for researchers and practitioners seeking to unravel the nuanced interplay between preventive maintenance, degradation, and complete failures within the context of a dual-unit system. At its core, the dataset encapsulates a temporal sequence of events, chronicling the life cycle of the system through detailed timestamps. These temporal markers form the backbone of the dataset, enabling the exploration of patterns, trends, and dependencies within the system's performance. The states of each unit, meticulously recorded over time, offer a granular understanding of the operational landscape. Distinctions between operational states, preventive maintenance intervals, and instances of degradation provide crucial insights into the conditions and transitions that shape the overall behavior of the two-unit system. Central to the dataset are records of complete failure events, providing a narrative of critical system breakdowns. These records encapsulate not only the timing and affected units but also the consequences that reverberate through the entire system, laying the groundwork for a profound analysis of failure modes. Degradation indicators, quantifying the gradual decline of one unit after complete failure, contribute a quantitative dimension to the dataset. These indicators may encompass various measures such as performance metrics, sensor data, or degradation indices, offering a means to gauge the evolving health of the system. Preventive maintenance records intricately weave into the fabric of the dataset, documenting strategic interventions aimed at preserving system integrity. The time stamped instances of preventive maintenance, coupled with details on the nature of the maintenance conducted, furnish a comprehensive account of proactive efforts to sustain system reliability. Operational parameters, ranging from environmental conditions to load variations, enrich the dataset by providing contextual information influencing the system's performance. These parameters offer a broader perspective on external factors shaping the system's behavior. Performance metrics, representing the overarching effectiveness of the two-unit system, become benchmarks for evaluating reliability and availability. These metrics, woven into the dataset, serve as indicators of the system's health and efficacy. The historical data embedded in the dataset acts as a backdrop, offering a contextual lens through which to interpret current behaviors and anticipate future trajectories. Moreover, the dataset delves into the effectiveness of preventive maintenance actions, gauging their impact on mitigating degradation and preventing failures. External factors, meticulously documented, amplify the dataset's scope by acknowledging influences from the broader operational environment. These factors encompass external disturbances, changes in operating conditions, or any external events that bear significance on the system's presentation. We obligate estimated various execution assessment confusion matrices (Recall, Accuracy Precision, and F1- Measure) to assess the performance of our model's implementation. The goal of the model phase evaluation is to assess the design model's generalization precision and accuracy using a test dataset that has not yet been observed.Here we intended this accuracy thru put on the exactness (Availability of the System), accuracy (Mean Time to System Failure(MTSF)), Recall (Proportional Busy Period of the Server), f_score function (Expected Fractional Number of repairman’s Visits (V_0)), that stand imported as of metrics module accessible into Scikit-learn Python archive that be contingent on the subsequent formula.In essence, the dataset unfolds as a narrative of the Two-Unit System's journey, providing a multidimensional exploration of its behavioral landscape. Optimal preventive maintenance scheduling takes center stage, with an inquiry into whether adjustments in timing and types of maintenance actions can yield improvements in system performance. The discussion revolves around the fine-tuning of preventive strategies for maximal impact. A panoramic view of system robustness and vulnerabilities is cast, considering both internal and external influences. As analysts embark on the journey of extracting insights from this dataset, they delve into the intricacies of system dynamics, seeking patterns, correlations, and opportunities to enhance reliability through informed decision-making.It is thinkable to establish which strictures are most important to the system's recital and to find the ideal values on behalf of apiece parameter by changing these and other important limitations one at a time and seeing how the system's output vagaries in response.

- Precision: Between these records of classified posts, messages, and news, precision shows the percentage of correctly identified sarcastic news messages. It describes how effective the suggested techniques are. Equation (6) provides the formula for estimating the Precision.

$$\text{ision} = \frac{\quad}{\quad} \tag{6}$$

- Recall: Recall displays the percentage of actual activity that includes sarcastic posts, news, and communications. It is also acknowledged that the recall is sensitive. One could estimate the values of Recall by applying the formula shown in Equation (7).

$$\text{cal} \quad = \frac{\quad}{\quad} \tag{7}$$

- F-Measure: The F-measure suggests evaluating all performance metrics based on the measured results of accuracy and recall. Equation (8) provides a formulation for estimating the values of the f-measure.

$$\text{asure} = \frac{\qquad}{\qquad} \tag{8}$$

VII. Results and Discussion

The temporal canvas of the system reveals nuanced patterns over time, portraying the ebb and flow of preventive maintenance actions, degradation events, and minimizes failures. By dissecting the temporal landscape, the analysis aims to uncover temporal trends and potential predictive insights that illuminate periods of heightened vulnerability or resilience. Within this temporal context, the reliability of each unit emerges as a focal point. Disparities in failure rates are scrutinized, and the effectiveness of preventive maintenance interventions is assessed. This unit-specific examination lays the foundation for a deeper understanding of the factors influencing overall system resilience. The quantitative analysis of degradation indicators in the unit post-complete failure provides valuable insights into the rate and nature of deterioration. This exploration not only dissects the degradation process but also unravels its ramifications for the broader health of the system. The evaluation extends to the effectiveness of preventive maintenance strategies. Beyond mere inspection, the analysis dissects the types and intervals of maintenance actions, seeking to unravel their influence on degradation mitigation and the prevention of minimize failures. System-level performance metrics, including reliability, availability, and mean time between failures, serve as critical barometers. These metrics encapsulate the overarching operational efficacy of the Two-Unit System, providing a quantitative lens through which to gauge its performance. The ensuing discussion navigates the terrain of results, offering a qualitative interpretation of the observed patterns and phenomena. It places a spotlight on temporal trends, unraveling their significance and exploring potential correlations with system vulnerabilities or robust periods. Unit-specific considerations form a pivotal part of the dialogue, addressing any observed disparities in failure rates or the efficacy of preventive maintenance. This unit-centric discussion lays the groundwork for tailored strategies to fortify specific components of the system. Strategies for managing and mitigating degradation in the unit post-complete failure are explored, with an emphasis on proactive measures. The discussion contemplates how interventions can be designed to arrest or decelerate the degradation process, enhancing overall system longevity. The discussion unfolds as a narrative that explores how the system responds to unexpected events, disturbances, and external factors. Comparisons with industry standards provide a benchmarking context, allowing for a critical assessment of whether observed behaviors align with established norms. This comparative analysis offers valuable insights into the system's standing within broader industry frameworks. In the synthesis of findings and discussions, practical recommendations emerge as guiding beacons. These recommendations are crafted to empower decision-makers with actionable insights for enhancing system reliability, optimizing preventive maintenance, and fortifying overall operational performance.

Table 4: *Table of parameter*

W(w1,w2,-------wn)	**ƛ(ƛ1,** ***n***)	**S(s,s2,-------sn)**	**p**
(0-.100)	**(0-.100)**	**(0-100)**	**(0-.68)**

Table 5: Performance of model

Model	MTSF	F1 Score(Expected Number of Inspections by the repair man)	Recall(Busy Period)	Precision(Availability of the System)
SGD	0.924	0.925	0.920	0.923
Adam	0.910	0.930	0.915	0.935
RMS Prop	0.923	0.927	0.918	0.930

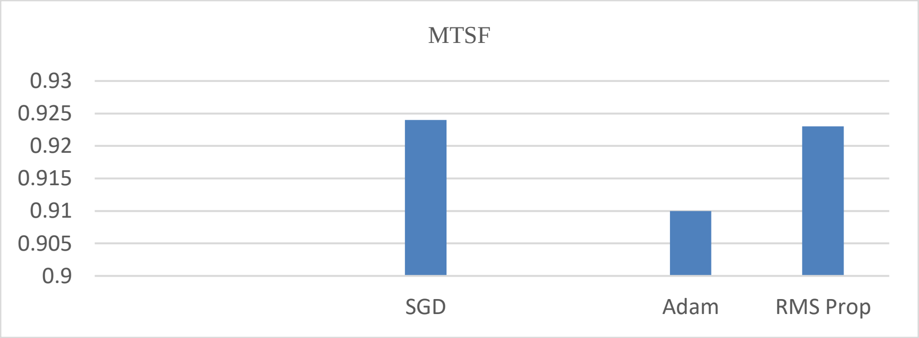

Figure 2: Compare all method using MTSF

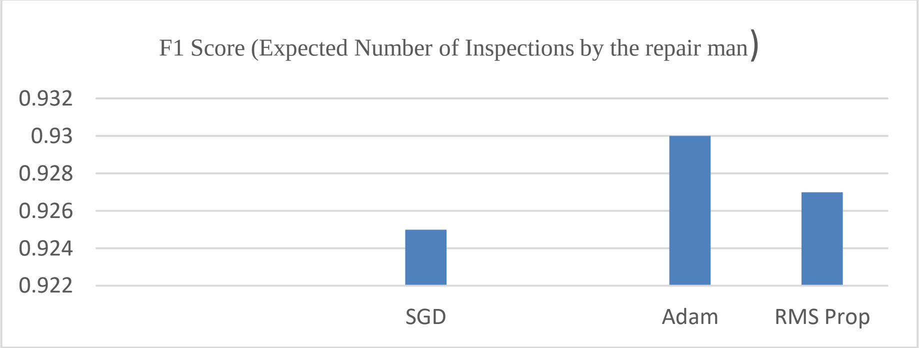

Figure 3: Compare all method using F1 Score

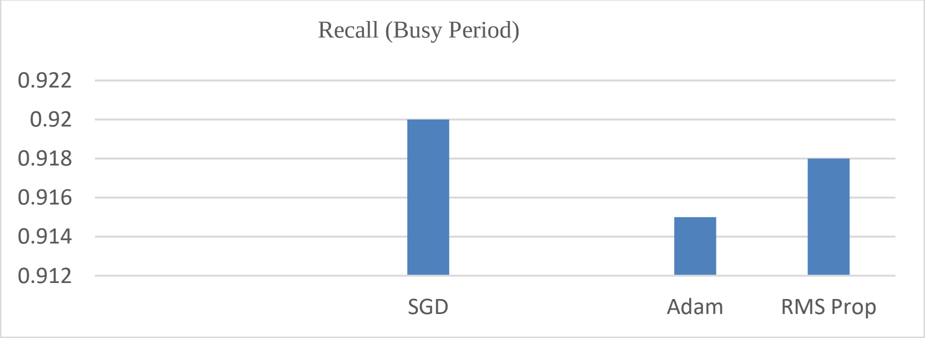

Figure 4: Compare all method using Recall

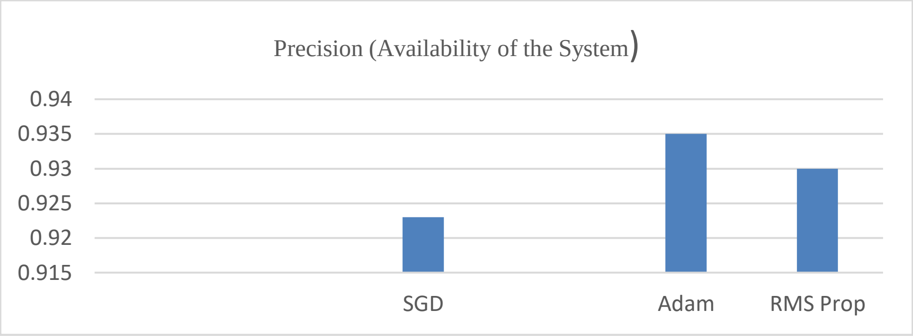

Figure 5: Compare all method using Precision

Using above table 4 and table 5 show draw graph Figure 2, Figure 3, Figure 4 and Figure 5. This model is train in three method (ADAM, SGD, and RMS Prop), in (MTSF of Adam is better than other two method. In Expected Number of Assessments by repair man of SGD is better than other two method. In Recall (Busy Period) of Adam is better than other two methods. In Precision (Availability of the System) of RMS Prop is better than other two method.

VIII. Conclusion

The behavioral analysis of a 2-unit system, incorporating PM and the introduction of degradation in single unit subsequently complete failure, yields comprehensive insights into the system's reliability and performance dynamics, Through a detailed examination, several significant conclusions emerge from the study. Firstly, the inclusion of preventive maintenance demonstrates a positive impact on the overall system reliability. Regular maintenance activities contribute to a reduction in the likelihood of unexpected failures, thereby enhancing the system's overall robustness. This, in turn, leads to increased availability, ensuring that both units are in optimal working condition for extended periods. However, the incorporation of degradation in one unit adds a layer of complexity to the system behavior. Degradation models provide a more realistic representation of the gradual decline in performance before complete failure occurs, allowing on behalf of a more nuanced sympathetic of the structure's behavior. The availability of the system is found to be intricately linked to the interplay between preventive maintenance and degradation. Striking the right balance between these factors becomes crucial in determining the system's ability to meet operational requirements. Optimization of maintenance strategies is paramount to minimizing downtime and maximizing availability effectively. Trade-off analysis reveals a delicate equilibrium between the cost of preventive maintenance and the potential savings derived from avoiding unexpected failures. This model is train in three methods (ADAM, SGD, and RMS Prop. In MTSFof Adam is better than other two methods. In Recall (Busy Period) of Adam is better than other two methods. In Precision (Availability of the System) of RMS Prop is better than other two method. Decision-makers must navigate this balance to determine the most cost-effective strategy for maintaining the system. Sensitivity analysis underscores the system's vulnerability to changes in various parameters such as maintenance intervals, degradation rates, and repair times. Identifying critical factors through sensitivity analysis is essential for informed decision-making and robust system design. Considering life-cycle costs', including maintenance and repair expenses, provides a comprehensive perspective on economic feasibility. Decision-makers must evaluate both short-term and long-term costs associated with chosen maintenance and operational strategies. The analysis also emphasizes the significance of risk mitigation. Identifying potential risks associated with system failures and degradation enables the implementation of proactive maintenance and monitoring strategies, thereby enhancing overall system resilience.

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