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Cost benefit study of two-unit system with dual maintenance under guarantee period

Dr. Shruti Rani Asstt. Prof. Of Mathematics Vaish College, Bhiwani

Abstract

This paper explain stochastic model having dual non-identical units. Here a routine inspection is carried out on the operating unit after doing a normal maintenance. It is also assumed that the operative unit is inspected if another unit is failed. After inspection either the unit is maintained or assumed to be failed after inspection. The decisions about failed unit is done by taking the concept of guarantee period. It is also considered that the unit under maintenance would not fail. After guarantee period, it is to be decided that whether minor replacement or major replacement. A new concept of paid maintenance is taken in this second part. This system is analyzed to determine various reliability measures by using mathematical tools MTSF/MTBF Markov chain, Markov Process. It is assumed that a repaired and replaced unit is good as new.

Keywords: Maintenance, Availability, Busy period, Inspection, Repair, Replacement

INTRODUCTION

In order to develop a good reliability program for a system, the system must have good reliability specifications. These specification most, if not all, of the conditions in the reliability definition including MTSF, limitations, operating environment instances, this will require a detailed description of how the system is expected to perform reliability- wise. A proper balance of financial goals and realistic performance are necessary to develop a detailed and balanced reliability specification. Another important foundation for a reliability program is the development of universally agreed upon definitions of the system failure. It should be fairly obvious whether a product has failed or not.

Reliability testing is the cornerstone of a reliability program. It provides the most detailed forms of data in that the data are collected can be carefully controlled and monitored. Furthermore, the reliability tests can be designed to uncover suspected failure modes and other problems.

The development of the new systems is directly or indirectly associated with improvement in the old systems and hence the efficiency. Thus assessment of reliability of equipment is of great importance in the context of rapidly growing technology and its further development. A large number of studies have been carried out to evaluate the reliability by taking two-unit models under different conditions.

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This paper explain stochastic model having dual non-identical units. Here a routine inspection is carried out on the operating unit after doing a normal maintenance. It is also assumed that the operative unit is inspected if another unit is failed. After inspection either the unit is maintained or assumed to be failed after inspection. The decisions about failed unit is done by taking the concept of guarantee period. It is also considered that the unit under maintenance would not fail. After guarantee period, it is to be decided that whether minor replacement or major replacement. A new concept of paid maintenance is taken in this second part. This system is analyzed to determine various reliability measures by using mathematical tools MTSF/MTBF Markov chain, Markov Process. It is assumed that a repaired and replaced unit is good as new.

Description of system and Assumption:-

In this paper, an operative unit is analyzed after a bound or definite period of its functioning and it is decided whether unit can run further or demand certain maintenance. A new concept of normal maintenance and major maintenance are introduced in this part.

> The system consists of two indistinguishable units - Initially one unit is functional and second unit is kept as cold standby.

System is supposed to be in Up-state if one unit is working and in down state if no unit is working.

Each unit of the system has two stages - normal operative or failed.

Firstly working unit is analyzed for normal maintenance before taken routine inspection.

After routine inspection it is to be decided that whether the unit needs major maintenance or the unit is unsuccessful under guarantee period.

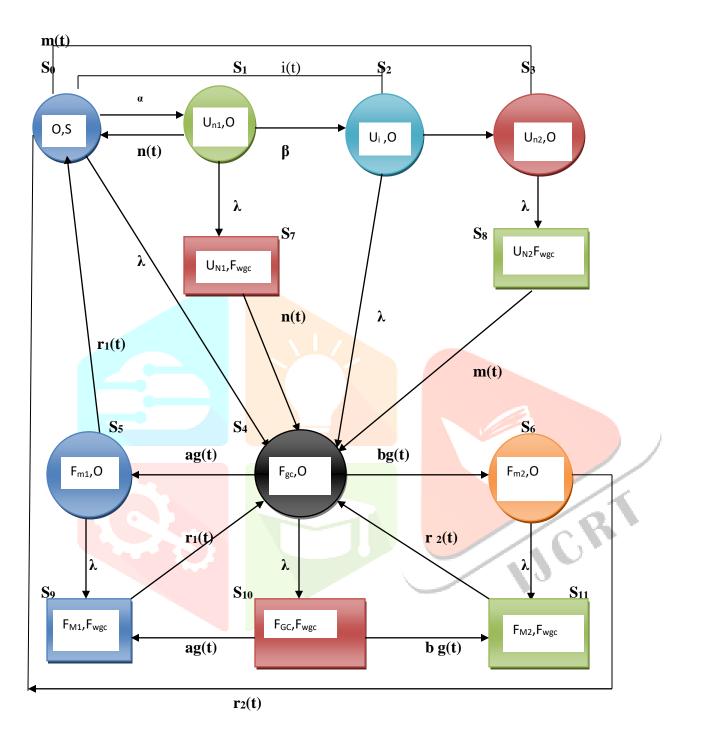
A unit under maintenance would not fail.

Check the guarantee of the failed unit, either it is in under the guarantee period or not.

Figure 1 If the unit is in the guarantee period, the failed unit is minor maintenance and if the unit is not under

the guarantee period then it is major maintenance.





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Notations	
Un1:	Normal maintenance
α:	Invariant normal maintenance rate of unit
i(t):	pdf of inspection time period of a unsuccessful unit
I(t):	cdf of inspection time period of a unsuccessful unit
β:	probability that unit is in under maintenance
Ui	Invariant inspection rate of unit
$U_{M1}U_{M2}$:	Maintenance of unit is continuous
F _{m1} :	unsuccessful unit under minor maintenance
F _{m2} :	unsuccessful unit under major maintenance
F _{gc:}	unsuccessful unit under guarantee check
Fwgc:	unsuccessful unit waiting for guarantee check
m(t)	Maintenance rate
$r_1(t)$	Minor maintenance rate
r ₂ (t)	Major maintenance rate
A:	$\{1-m^*(\lambda)\}$
B:	$\{1-g^*(\lambda)\}$
C:	$\{1-r_1^*(\lambda)\}$
D:	$\{1-r_2^*(\lambda)\}$
The system can be	in any of the following states with respect of the above symbol $RS_0 =$
(O,S)	$RS_1 = (U_n O)$

	(O,S)	$RS_1 =$	(U _{n1} ,O)
	$\mathbf{RS}_2 = (\mathbf{U}_{\mathbf{i}}, \mathbf{O})$		$\mathbf{RS}_3 = (\mathbf{F}_{n2}, \mathbf{O})$
	$\mathbf{RS}_4 = (\mathbf{F}_{gc}, \mathbf{O})$		$\mathbf{RS}_5 = (\mathbf{F}_{\mathrm{m1}}, \mathbf{O})$
	$\mathbf{RS}_6 = (\mathbf{F}_{\mathrm{m2}}, \mathbf{O})$		$\mathbf{RS}_7 = (\mathbf{F}_{\mathbf{N}1}, \mathbf{F}_{\mathbf{wgc}})$
RS_8	= (F _{N2} ,F _{wgc})	RS ₉	= (U _{M 1} ,F _{wgc})
RS_{10}	= (F _{M 2} ,F _{wgc})	RS ₉	= (F _{GC} , F _{wgc})

Transition Probabilities

The era of entering into states $\{RS_0, RS_1, RS_2, RS_3, RS_4, RS_5, RS_6\}$ are

Renewed states. The change of state probabilities from RS_k to RS_l states are given by Q_{kl} and in the steady states Tp_{kl} denotes the change of state probability from states RS_k to RS_l are given under

Tp_{01}	=	$\alpha/(\alpha+\lambda)$	Tp_{04}	=	$\lambda/(\alpha+\lambda)$
Tp_{10}	=	$n^*(\beta+\lambda)$	Tp_{12}	=	β {1- n [*] (β + λ)}/((β + λ))
Tp_{17}	=	$\lambda \{1-n^*(\beta+\lambda)\}/((\beta+\lambda))$	Tp_{20}	=	$i^*(\gamma+\lambda)$
Tp ₂₃	=	γ {1- n [*] (γ + λ)}/((γ + λ))	$Tp_{12} \\$	=	$\lambda \{1-n^*(\gamma+\lambda)\}/((\gamma+\lambda))$
Tp ₃₀	=	$m^*(\lambda)$	Tp ₃₈	=	А
$Tp_1^{7}_4$	=	λ {1- n [*] (β + λ)}/((β + λ))		$Tp_{3}^{8}{}_{4}$	= A
Tp ₄₅	=	$ag^*(\lambda)$		Tp_{46}	$=$ bg [*] (λ)
Tp _{4,10}		В		$Tp_4^{10,9}$	$B_4 = B$
$Tp_{4}^{10,1}$	¹ 4=	В		Tp50	$=$ $r_1^*(\lambda)$
Tp ₅₉	=	С		$Tp_5^{9}_4$	= C
Tp ₆₀	=	$r_2^*(\lambda)$		Tp_{6}^{11} 4	= D
Tp _{6,11}	=	D			

With the help of following calculated values, we can easily check that

 $Tp_{01} + Tp_{04} = 1$ $Tp_{10} + Tp_{12} + Tp_{17} = 1$ $Tp_{20} + Tp_{23} + Tp_{24} = 1$ $Tp_{30} + Tp_{38} = 1$ **Tp**₁₇ $Tp_{1}^{7}_{4}$ = Tp₃₈ $Tp_{3}^{8}_{4}$ = $Tp_{45} + Tp_{46} + Tp_{4,10} = 1$ $Tp_4^{10,9}4$ $Tp_{4'10} =$ Tp4^{10,11}4 $Tp_{4'10} =$ $Tp_{50} + Tp_{59} = 1$ Tp₅₉ $Tp_5^{9}_4$ = $Tp_{60} + Tp_{6,11} =$ 1 $Tp_{6}^{,11}_{4}$ $Tp_{6'11} =$

Mean Sojourn Times

 $m_{6,11}$

To compute mean value of stay/sojourn time $\mu_k(t)$ for state RS_k, let T_k be sojourn time for state RS_k. Then

 $\mu_{k}(t) = \lim_{t \to \infty} \int_{0}^{t} P[t:0 < t < T] dt$ So that in steady state we have following relations $1/\alpha + \lambda$ $\{1-n^*(\beta+\lambda)\}/(\beta+\lambda)$ = μ_1 = μ_0 $\{1-i^*(\gamma+\lambda)\}/(\gamma+\lambda)$ = μ3 = A/λ μ_2 Β/λ C/λ = μ5 μ4 = D/λ = μ6 $\lambda/(\alpha+\lambda)^2$ The unconditional mean time is mathematically given by $m_{kl} = \int_{0}^{} t dQ_{kl}(t) = -q_{kl}^{*}(s)'_{at s=0}$ $\alpha/(\alpha+\lambda)^2$ So that m₀₄ m_{01} $-n^{*'}(\beta+\lambda)$ m_{10} = $[\beta \{1 - n^*(\beta + \lambda)\}/(\beta + \lambda)n^2] + \beta n^{*'}(\beta + \lambda)/(\beta + \lambda)$ m₁₂ = $[\lambda \{1 - n^*(\beta + \lambda)\}/(\beta + \lambda)n^2] + \lambda n^{*'}(\beta + \lambda)/(\beta + \lambda)$ m17 = $-i^{*}(\gamma+\lambda)$ m_{20} = $[\gamma \{1 - i^*(\gamma + \lambda)\}/(\gamma + \lambda)^2] + \gamma i^{*'}(\gamma + \lambda)/(\gamma + \lambda)$ m₂₃ = $[\lambda \{1 - i^*(\gamma + \lambda)\}/(\gamma + \lambda)^2] + \gamma i^*(\gamma + \lambda)/(\gamma + \lambda)$ = m₂₄ $-m^{*}(\lambda)$ $A/\lambda - m^{*}(\lambda)$ = m₃₀ = m38 $-ag^{*'}(\lambda)$ $-bg^{*'}(\lambda)$ = m46 = m45 $A/\lambda - g^{*'}(\lambda)$ m_{50} = $-r_1^{*'}(\lambda)$ = $m_{4,10}$ $C/\lambda - r_1^{*'}(\lambda)$ = $-r_2^{*'}(\lambda)$ m59 = m_{60} $D/\lambda - r_2^{*'}(\lambda)$ =

It can be easily verified that

```
m_{01} +
                  m_{04}
                                      \mu_0
m_{10} + m_{12} + m_{17} = \mu_1
m_{20} + m_{23} + m_{24} = \mu_2
m_{30} + m_{38} = \mu_3
m_{40} + m_{46} + m_{4,10} = \mu_4
m50 +
             m_{59} = \mu_5
m<sub>60</sub> +
            m_{6,11} = \mu_6
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Mean Time to System Failure

The recursive relations for (MTSF) are given by the following equations

 $= \mathbf{Q}_{01} \ \Theta \ \boldsymbol{\Omega}_1 + \ \mathbf{Q}_{04} \ \Theta \ \boldsymbol{\Omega}_4$ Ω_0 Ω_1 $= Q_{10} \ \odot \Omega_0 + Q_{12} \ \odot \Omega_2 + Q_{17}$ $= \mathbf{Q}_{20} \ \Theta \ \Omega_0 + \mathbf{Q}_{23} \Theta \Omega_3 + \mathbf{Q}_{24} \ \Theta \Omega_4$ Ω_2 Ω_3 $= Q_{30} \Theta \Omega_0 + Q_{38}$ $= Q_{45} \odot \Omega_5 + Q_{46} \odot \Omega_6 + Q_{4,10}$ Ω_4 Ω_{5} $= Q_{50} \odot \Omega_0 + Q_{59}$ $= Q_{60} \Theta \Omega_0 + Q_{6.11}$ Ω_{6}

Here Ω_i and q_{kl} are all function of t

Above these equation can be Solving by taking L. S.T and solving for $\Omega_0^{**}(s)$,

 $\Omega_0^{**}(s) = \frac{U(s)}{V(s)}$

we get Where

MTSF =
$$\Omega_0$$
 = $\lim_{s \to 0} [\{1 - \Omega_0^{**}(s)\}/s]$
= $\{V'(0) - U'(0)\}/V(0)$
= $\frac{U}{V}$

After solving, we have

JCR $U(s) = - \left[q_{01} q_{17} + q_{01} q_{12} q_{23} q_{38} + q_{01} q_{12} q_{24} q_{4,10} + q_{01} q_{12} q_{24} q_{45} q_{59} \right]$ $+ q_{01} q_{12} q_{24} q_{46} q_{6,11} + q_{04} q_{4,10} + q_{04} q_{45} q_{59} + q_{04} q_{46} q_{6,11}$ V(s) $- \frac{1}{901} + \frac{$ = $+ q_{01} q_{12} q_{24} q_{46} q_{60} + q_{04} q_{45} q_{50} + q_{04} q_{46} q_{60}$ Where $U = V(0) - U(0) = - [1 + Tp_{01} \mu_1 + Tp_{01} Tp_{12} \mu_2 + Tp_{01} Tp_{12} Tp_{23} \mu_3 + (Tp_{04} + Tp_{01} Tp_{12} Tp_{24})]$ $(\mu_5 + Tp_{45}\mu_5 + Tp_{46}\mu_6)$] $V = V(0) = -1 + Tp_{01} Tp_{10} + Tp_{12} Tp_{01} (Tp_{20} + Tp_{23} Tp_{30}) -$

 $(Tp_{01} Tp_{12} Tp_{24} + Tp_{04})(Tp_{45} Tp_{50} + Tp_{46} Tp_{60})$

Availability of the system -(Av)-

The recursive relations for the availability $Av_i(t)$ at each point of the system is given by

 $Av_0 = q_{01} \Delta Av_1 + q_{04} \Delta Av_2 + \Psi_0$ $Av_1 = q_{10} \Delta Av_0 + q_{12} \Delta Av_2 + q_1^7 \Delta Av_4 + \Psi_1$ $Av_2 = q_{20} \Delta Av_0 + q_{23}\Delta Av_3 + q_{24}\Delta Av_4 + \Psi_2$ $Av_3 = q_{30} \Delta Av_0 + q_3^{8}_4 \Delta Av_4 + \Psi_3$ Av₄=q₄₅ Δ Av₅+q₄₆ Δ Av₆+ (q₄^(10,9)₃+ q₄^(10,11)₄) Δ Av₄+ Ψ ₄ $Av_5 = q_{50} \Delta Av_0 + q_5^{(9)} \Delta Av_4 + \Psi_5$ $Av_6 = q_{60} \Delta Av_0 + q_6^{(11)} \Delta Av_3 + \Psi_6$

Here Av_i , Ψ and q_{kl} are all function of t

$ \begin{aligned} \Psi_{2} &= \\ \Psi_{4} &= \\ \Psi_{6} &= \\ \end{aligned} $ Now solving these equations of the steady states avail $Av_{0}^{**} = 0$ Where $ \begin{aligned} U_{1}(0) &= -[\{\mu_{0} + Tp_{60}\} + (\mu_{4} + Tp_{45}\mu_{5} + Tp_{4})] + (\mu_{4} + Tp_{45}\mu_{5} + Tp_{4}) \\ \end{bmatrix} $ Where $ \begin{aligned} V_{1}'(0) &= -[(\mu_{1} + Tp_{45}\mu_{5} + Tp_{45}\mu_{6})] + (\mu_{4} + Tp_{45}\mu_{5} + Tp_{45}\mu_{6})] \\ Normal Maintenance The recursive relations Nm_{0} &= q_{01} \Delta Nm_{1} + q_{0} \\ Nm_{1} &= q_{10} \Delta Nm_{0} + q_{0} \\ Nm_{3} &= q_{30} \Delta Nm_{0} + q_{0} \\ Nm_{5} &= q_{50} \Delta Nm_{0} + q_{0} \\ Nm_{6} &= q_{60} \Delta Nm_{0} + q_{0} \\ Nm_{6} &= q_{60} \Delta Nm_{0} + q_{0} \\ Now solving these equations \begin{aligned} \P_{0}^{*}(s) &= U_{2}(s)/V_{1}(s) \\ Then for steady states \\ \P_{0}^{**} &= \lim_{s \to 0} (s \P_{0}^{*}(s)) = U_{2} \\ Where \end{aligned} V1(0) is specified in equations \begin{aligned} Mm_{0} &= q_{01} \Delta Mm_{1} + q_{0} \\ Mm_{1} &= q_{10} \Delta Mm_{1} + q_{0} \\ \end{aligned} $	$=$ $=$ $Av_0^*($ $abilit$ $U_1 (0)$ $-\mu_1 T$ $p_{46}\mu_6$ $(1+T]$ $Tp_{24} -$ $Time$		$(s) /V_{1}$ (s) /V_{1} (s) /V_{1} (s) /V_{1} (Tp_{0}) /Tp_{0} /Tp	(s) +Tp ₀₄) Tp ₁₂ +T)µ2 + (7 p ₀₁ +Tp 12 Tp ₂₃ +	Гр ₁₂ Тр 904)	μ_1 lving for $Av_0^*(s)$, we get $1 Tp_{23} + Tp_{04} Tp_{23})\mu_3 + (Tp_{45} Tp_{50} + Tp_{46} + Tp_{01}(Tp_{12} Tp_{24} + Tp_1^{7}_4)]$
$\Psi_{4} = \Psi_{6}$ $\Psi_{6} = \Psi_{6}$ Now solving these equations are stated with the steady states avail $\Delta v_{0}^{**} = \Psi_{6}$ $U_{1}(0) = -[\{\mu_{0}+1, \mu_{0}\}, \mu_{0}+1, $	$=$ $=$ $Av_0^*($ $abilit$ $U_1 (0)$ $-\mu_1 T$ $p_{46}\mu_6$ $(1+T]$ $Tp_{24} -$ $Time$	μ4 μ6 s by taki (t) = U1 ty is give)) / V1(0) 2 2 (Tp23 V1(0): p01 Tp12 + Tp01 T	$(s) /V_{1}$ (s) /V_{1} (s) /V_{1} (s) /V_{1} (Tp_{0}) /Tp_{0} /Tp	$Ψ_5$ lace tra (s) +Tp ₀₄ Tp ₁₂ +T	= $(\mu_2 + (T_{p_{01}})\mu_2 + (T_{p_{01}})\mu_2 + (T_{p_{01}})\mu_2$	μ_5 and so $\Gamma p_{12} T p_{004}$	01 Tp ₂₃ + Tp ₀₄ Tp ₂₃) μ_3 +(Tp ₄₅ Tp ₅₀ + Tp ₄₆ +Tp ₀₁ (Tp ₁₂ Tp ₂₄ + Tp ₁ ⁷ ₄ }]
	$=$ ations $Av_0^*($ abilit $U_1(0)$ $-\mu_1 T_1$ $(1+T_1)$ $\Gamma p_{24} - $ $Time$	μ_{6} s by taki (t) = U ₁ ty is give)) / V ₁ (0) $\mu_{01} + (Tp_{23} - V_1(0))$ $\mu_{01} Tp_{12} + Tp_{01} T$	$(s) /V_{1}$ (s) /V_{1} (s) /V_{1} (s) /V_{1} (Tp_{0}) /Tp_{0} /Tp	lace tra (s) $+Tp_{04}$ $Tp_{12}+T$ $p_{01}Tp_{11}$	$(\mu_2 + (1))\mu_2 + (1)\mu_2 + (1)\mu_2$	and so $\Gamma p_{12} T p_{004}$	01 Tp ₂₃ + Tp ₀₄ Tp ₂₃) μ_3 +(Tp ₄₅ Tp ₅₀ + Tp ₄₆ +Tp ₀₁ (Tp ₁₂ Tp ₂₄ + Tp ₁ ⁷ ₄ }]
Now solving these equations The steady states avail $Av_0^{**} = 1$ Where $U_1(0) = -[\{\mu_0 + Tp_{60}\} + (\mu_4 + Tp_{45}\mu_5 + Tp_4)]$ And $V_1'(0) = -[(Tp_{23}Tp_3^{8}_4 + Tp_{01}Tp_{12}T)]$ $(\mu_4 + Tp_{45}\mu_5 + Tp_{46}\mu_6)$ Normal Maintenance The recursive relations Nm_0 = q_{01} \Delta Nm_1 + q_{0} Nm 1 = q_{10} \Delta Nm_0 + 1 Nm_2 = q_{20} \Delta Nm_0 + 1 Nm_3 = q_{30} \Delta Nm_0 + q_{0} Nm 4=q45 Δ Nm_5+q46 Δ Nm 5 = q_{50} Δ Nm_0 + q_{0} Nm 6 = q_{60} Δ Nm_0 + q_{0} Now solving these equations $\P_0^*(s) = U_2(s)/V_1(s)$ Then for steady states $\P_0^*(s) = U_2(s)/V_1(s)$ $\Pi_1 = q_{10} \Delta Mm_1 + 1$ Mm 1 = q_{10} ΔMm_0	ations $Av_0^*($ abilit U_1 (0 $-\mu_1$ T $p_{46}\mu_6$ $(1+T_1)$ Γp_{24} - Time	s by taki (t) = U ty is give)) / $V_1(0)$ $p_{01}+(Tp)$) {(Tp_{23} $V_1(0)$ $v_1(0)$ $p_{01} Tp_{12}$ + $Tp_{01} T$	$(s) /V_{1}$ (s) /V_{1} (s) /V_{1} (s) /V_{1} (Tp_{0}) /Tp_{0} /Tp	(s) +Tp ₀₄) Tp ₁₂ +T)µ2 + (7 p ₀₁ +Tp 12 Tp ₂₃ +	Гр ₁₂ Тр 904)	01 Tp ₂₃ + Tp ₀₄ Tp ₂₃) μ_3 +(Tp ₄₅ Tp ₅₀ + Tp ₄₆ +Tp ₀₁ (Tp ₁₂ Tp ₂₄ + Tp ₁ ⁷ ₄ }]
The steady states avail $Av_0^{**} = 0$ Where $U_1(0) = -[\{\mu_0 + Tp_{60}\} + (\mu_4 + Tp_{45}\mu_5 + Tp_4)]$ And $V_1(0) = -[(0, Tp_{23}Tp_3^{8}_4 + Tp_{01}Tp_{12}T_4)]$ $(\mu_4 + Tp_{45}\mu_5 + Tp_{46}\mu_6)$ Normal Maintenance The recursive relations $Nm_0 = q_{01} \Delta Nm_1 + q_4$ $Nm_1 = q_{10} \Delta Nm_0 + q_4$ $Nm_2 = q_{20} \Delta Nm_0 + q_4$ $Nm_3 = q_{30} \Delta Nm_0 + q_4$ $Nm_5 = q_{50} \Delta Nm_0 + q_4$ $Nm_6 = q_{60} \Delta Nm_0 + q_4$ $Nm_6 = q_{60} \Delta Nm_0 + q_6$ Now solving these equations $\P_0^*(s) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s\P_0^*(s)) = U_2(s)/V_1(s)$ Then	$Av_0^*($ abilit $U_1(0)$ $-\mu_1 T_1^*(0)$ $(1+T_1)$ $(1+T_2)$ $Tp_{24} - 1$ Time		$(s) /V_{1}$ (s) /V_{1} (s) /V_{1} (s) /V_{1} (Tp_{0}) /Tp_{0} /Tp	(s) +Tp ₀₄) Tp ₁₂ +T)µ2 + (7 p ₀₁ +Tp 12 Tp ₂₃ +	Гр ₁₂ Тр 904)	01 Tp ₂₃ + Tp ₀₄ Tp ₂₃) μ_3 +(Tp ₄₅ Tp ₅₀ + Tp ₄₆ +Tp ₀₁ (Tp ₁₂ Tp ₂₄ + Tp ₁ ⁷ ₄ }]
The steady states avail $Av_0^{**} = 1$ Where $U_1(0) = -[\{\mu_0 + Tp_{60}\} + (\mu_4 + Tp_{45}\mu_5 + Tp_4)]$ And $V_1'(0) = -[(Tp_{23}Tp_3^8 + Tp_{01}Tp_{12}T)]$ $(\mu_4 + Tp_{45}\mu_5 + Tp_{46}\mu_6)$ Normal Maintenance The recursive relations Nm_0 = q_{01} \Delta Nm_1 + q_{01} Nm_1 = q_{10} \Delta Nm_0 + 1 Nm_2 = q_{20} \Delta Nm_0 + 1 Nm_3 = q_{30} \Delta Nm_0 + q_{01} Nm 4=q45 $\Delta Nm_5 + q_{46} \Delta$ Nm 5 = q_{50} $\Delta Nm_0 + q_{01}$ Nm 6 = q_{60} $\Delta Nm_0 + q_{01}$ Now solving these equat $\P_0^*(s) = U_2(s)/V_1(s)$ Then for steady states $\P_0^*=\lim_{s\to 0} (s\P_0^*(s)) = U_2$ Where $V_1'(0)$ is specified in equations $Mm_0 = q_{01} \Delta Mm_1 + 1$ $Mm_1 = q_{10} \Delta Mm_0 - 1$	abilit U ₁ (0 - μ_1 T p46 μ_6 (1+T] Tp24 - Time	ty is give $(p_{01} + (Tp_{01} + (Tp_{02} + Tp_{01} + (Tp_{02} + Tp_{01} +$	en by 12 Tpo1 Tp3 ⁸ 4('=0 + μ_0 (T $p_1^{7}_4$ + T	+Tp ₀₄) Tp ₁₂ +T	$p_{01}+Tp_{12}$	004)	$+Tp_{01}(Tp_{12}Tp_{24}+Tp_{1}^{7}_{4})]$
$Av_{0}^{**} = 0$ Where $U_{1}(0) = -[\{\mu_{0}+Tp_{60}\} + (\mu_{4}+Tp_{45}\mu_{5}+Tp_{45}\mu_{5}+Tp_{4}]$ And $V_{1}(0) = -[(0, Tp_{23}Tp_{3}^{8}+Tp_{01}Tp_{12}Tp_{4}]$ $(\mu_{4}+Tp_{45}\mu_{5}+Tp_{46}\mu_{6})$ Normal Maintenance The recursive relations $Nm_{0} = q_{01} \Delta Nm_{1} + q_{4}$ $Nm_{1} = q_{10} \Delta Nm_{0} + q_{4}$ $Nm_{2} = q_{20} \Delta Nm_{0} + q_{4}$ $Nm_{3} = q_{30} \Delta Nm_{0} + q_{4}$ $Nm_{5} = q_{50} \Delta Nm_{0} + q_{4}$ $Nm_{5} = q_{50} \Delta Nm_{0} + q_{4}$ $Nm_{6} = q_{60} \Delta Nm_{0} + q_{6}$ $Now solving these equations \P_{0}^{*}(s) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) Then for steady states\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}(s)/V_{1}(s) \Psi_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{1}(s)/V_{1}(s)$	U ₁ (0 -µ ₁ T p46µ6 (1+T] Гр24 - Time	$V_{1}(0) / V_{1}(0)$ $V_{1}(0) + (Tp_{23}) + (Tp_{23}) + (Tp_{12}) + Tp_{01} Tp_{12}$) $Tp_{3} Tp_{01}$ $Tp_{3} t^{8} 4(t)$ =0 $+ \mu_{0} (T)$ $Tp_{1}^{7}t_{4} + T$	$Tp_{12}+T$ $p_{01} Tp_{12}$	$p_{01}+Tp_{12}$	004)	$+Tp_{01}(Tp_{12}Tp_{24}+Tp_{1}^{7}_{4})]$
Where $U_{1}(0) = -[\{\mu_{0}+1\}]$ $Tp_{60}) + (\mu_{4}+Tp_{45}\mu_{5}+Tp_{4}]$ And $V_{1}'(0) = -[(\mu_{0}+1)]$ $(\mu_{4}+Tp_{45}\mu_{5}+Tp_{46}\mu_{6})$ Normal Maintenance The recursive relations Nm_{0} = q_{01} \Delta Nm_{1} + q_{10} Nm_{1} = q_{10} \Delta Nm_{0} + q_{10} Nm $_{3} = q_{30} \Delta Nm_{0} + q_{10}$ Nm $_{4} = q_{45} \Delta Nm_{5} + q_{46} \Delta$ Nm $_{5} = q_{50} \Delta Nm_{0} + q_{10}$ Now solving these equations Now solving these equations $\eta_{0}^{*}(s) = U_{2}(s)/V_{1}(s)$ Then for steady states $\eta_{0}^{**} = \lim_{s \to 0} (s \eta_{0}^{*}(s)) = U_{2}$ Where V_{1}'(0) is specified in equations Mm_{0} = q_{01} \Delta Mm_{1} + q_{10} \Delta Mm_{1}	-μ ₁ Τ 546μ6 (1+Τ] Γp ₂₄ - Time	$p_{01}+(Tp) $ $\{(Tp_{23} V_1(0)) $ $V_1(0) $ $p_{01} Tp_{12} $ $+ Tp_{01} T$	$\begin{array}{c} & Tp_{012} Tp_{01} \\ Tp_3 {}^8 4('=0) \\ & + \mu_0 (Tp_1^{7}_{4} + T) \end{array}$	$Tp_{12}+T$ $p_{01} Tp_{12}$	$p_{01}+Tp_{12}$	004)	$+Tp_{01}(Tp_{12}Tp_{24}+Tp_{1}^{7}_{4})]$
$U_{1}(0) = -[\{\mu_{0}+1\}]$ $Tp_{60}) + (\mu_{4}+Tp_{45}\mu_{5}+Tp_{4}]$ And $V_{1}(0) = -[(0]$ $Tp_{23}Tp_{3}^{8}_{4} + Tp_{01}Tp_{12}T_{4}$ $(\mu_{4}+Tp_{45}\mu_{5} + Tp_{46}\mu_{6})$ Normal Maintenance The recursive relations $Nm_{0} = q_{01} \Delta Nm_{1} + q_{4}$ $Nm_{1} = q_{10} \Delta Nm_{0} + q_{4}$ $Nm_{2} = q_{20} \Delta Nm_{0} + q_{4}$ $Nm_{3} = q_{30} \Delta Nm_{0} + q_{4}$ $Nm_{5} = q_{50} \Delta Nm_{0} + q_{4}$ $Nm_{6} = q_{60} \Delta Nm_{0} + q_{6}$ Now solving these equat $\P_{0}^{*}(s) = U_{2}(s)/V_{1}(s)$ Then for steady states $\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}^{**}$ $Where$ $V_{1}(0) \text{ is specified in equations}$ $Mm_{0} = q_{01} \Delta Mm_{1} + q_{10} \Delta Mm_{1}$	р46µ6) (1+Т] Гр24 - Tim o) { $(Tp_{23} V_1(0))$ V ₁ (0) $p_{01} Tp_{12}$ + Tp ₀₁ T	$Tp_3 {}^8 4(1)^{-1}$	$Tp_{12}+T$ $p_{01} Tp_{12}$	$p_{01}+Tp_{12}$	004)	$+Tp_{01}(Tp_{12}Tp_{24}+Tp_{1}^{7}_{4})]$
Tp ₆₀) +(μ 4+Tp ₄₅ μ 5 +Tp And $V_1'(0) = - [(C_1 Tp_{23} Tp_3^{8} + Tp_{01} Tp_{12} T)]$ (μ 4+ Tp ₄₅ μ 5 + Tp ₄₆ μ 6) Normal Maintenance The recursive relations Nm ₀ = q ₀₁ Δ Nm ₁ + C_1 Nm ₁ = q ₁₀ Δ Nm ₀ + C_2 Nm ₃ = q ₂₀ Δ Nm ₀ + C_2 Nm ₄ =q ₄₅ Δ Nm ₅ +q ₄₆ Δ Nm ₅ = q ₅₀ Δ Nm ₀ + C_2 Nm ₆ = q ₆₀ Δ Nm ₀ + C_2 Now solving these equations ¶ ₀ *(s) = U ₂ (s)/V ₁ (s) Then for steady states ¶ ₀ **= $\lim_{s\to 0} (s \P_0^*(s)) = U_2 C_2$ Where V ₁ '(0) is specified in equations Mm ₀ = q ₀₁ Δ Mm ₁ + $Mm_1 = q_{10} \Delta$ Mm ₀ -	р46µ6) (1+Т] Гр24 - Tim o) { $(Tp_{23} V_1(0))$ V ₁ (0) $p_{01} Tp_{12}$ + Tp ₀₁ T	$Tp_3 {}^8 4(1)^{-1}$	$Tp_{12}+T$ $p_{01} Tp_{12}$	$p_{01}+Tp_{12}$	004)	$+Tp_{01}(Tp_{12}Tp_{24}+Tp_{1}^{7}_{4})]$
And $V_1(0) = - [(C_1 + C_2)^2 + C_2 + C_2)^3 + C_3 + C_4 $	(1+Τ _] Γp ₂₄ - 	$V_1(0)$ $p_{01} Tp_{12}$ $+ Tp_{01} T$	=0 + μ_0 (T $p_1^{7}_{4}$ + T	['] p ₀₁ Tp ₁	12 Tp 23+		
$V_1(0) = - [($ $Tp_{23} Tp_3^{8} + Tp_{01} Tp_{12} T)$ $(\mu_4 + Tp_{45}\mu_5 + Tp_{46}\mu_6)$ Normal Maintenance The recursive relations $Nm_0 = q_{01} \Delta Nm_1 + q$ $Nm_1 = q_{10} \Delta Nm_0 + q$ $Nm_2 = q_{20} \Delta Nm_0 + q$ $Nm_3 = q_{30} \Delta Nm_0 + q$ $Nm_4 = q_{45} \Delta Nm_5 + q_{46} \Delta$ $Nm_5 = q_{50} \Delta Nm_0 + q$ $Nm_6 = q_{60} \Delta Nm_0 + q$ $Now solving these equa$ $\P_0^*(s) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s \P_0^*(s)) = U_2$ <i>Where</i> $V_1(0) \text{ is specified in equations}$ $Mm_0 = q_{01} \Delta Mm_1 + q$ $Mm_1 = q_{10} \Delta Mm_0 - q$	Гр ₂₄ - Tim	$p_{01} Tp_{12}$ + Tp_{01} T	$^{+} \mu_{0} (T)$	`р ₀₁ Тр ₁ р ₀₄ Тр2	12 Tp ₂₃ ⊣	⊦ Tp ₀₄ T	
Tp ₂₃ Tp ₃ ⁸ ₄ + Tp ₀₁ Tp ₁₂ T (μ 4+ Tp ₄₅ μ 5 + Tp ₄₆ μ 6) Normal Maintenance The recursive relations Nm ₀ = q ₀₁ Δ Nm ₁ + α Nm ₁ = q ₁₀ Δ Nm ₀ + α Nm ₂ = q ₂₀ Δ Nm ₀ + α Nm ₃ = q ₃₀ Δ Nm ₀ + α Nm 4=q ₄₅ Δ Nm ₅ +q ₄₆ Δ Nm 5 = q ₅₀ Δ Nm ₀ + α Nm 6 = q ₆₀ Δ Nm ₀ + α Now solving these equa ¶ ₀ *(s) = U ₂ (s)/V ₁ (s) Then for steady states ¶ ₀ **= lim (s¶ ₀ *(s)) = U ₂ Where V ₁ (0) is specified in equal Paid Maintenance Tim The recursive relations Mm ₀ = q ₀₁ Δ Mm ₁ + Mm ₁ = q ₁₀ Δ Mm ₀ -	Гр ₂₄ - Tim	+ Tp ₀₁ T	$p_1^{7}_{4} + T$	[`] р ₀₁ Тр ₁ р ₀₄ Тр ₂	12 Tp ₂₃ +	⊦ Тр₀₄ Т	
Tp ₂₃ Tp ₃ ⁸ ₄ + Tp ₀₁ Tp ₁₂ T (μ 4+ Tp _{45μ5} + Tp _{46μ6}) Normal Maintenance The recursive relations Nm ₀ = q ₀₁ Δ Nm ₁ + α Nm ₁ = q ₁₀ Δ Nm ₀ + α Nm ₂ = q ₂₀ Δ Nm ₀ + α Nm ₃ = q ₃₀ Δ Nm ₀ + α Nm 4=q ₄₅ Δ Nm ₅ +q ₄₆ Δ Nm 5 = q ₅₀ Δ Nm ₀ + α Nm 6 = q ₆₀ Δ Nm ₀ + α Now solving these equations ¶ ₀ *(s) = U ₂ (s)/V ₁ (s) Then for steady states ¶ ₀ **= $\lim_{s\to 0} (s¶_0^*(s)) = U_2$ Where V ₁ '(0) is specified in equations Mm ₀ = q ₀₁ Δ Mm ₁ + Mm ₁ = q ₁₀ Δ Mm ₀ -	Гр ₂₄ - Tim	+ Tp ₀₁ T	$p_1^{7}_{4} + T$	$p_{01} Tp_1 p_1 p_0 Tp_2$	12 Tp ₂₃ +	⊢ Tp ₀₄ T	
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(μ_4 + Tp ₄₅ μ_5 + Tp ₄₆ μ_6) Normal Maintenance The recursive relations Nm ₀ = q ₀₁ Δ Nm ₁ + α Nm ₁ = q ₁₀ Δ Nm ₀ + α Nm ₂ = q ₂₀ Δ Nm ₀ + α Nm ₃ = q ₃₀ Δ Nm ₀ + α Nm ₄ =q ₄₅ Δ Nm ₅ +q ₄₆ Δ Nm ₅ = q ₅₀ Δ Nm ₀ + α Nm ₆ = q ₆₀ Δ Nm ₀ + α Now solving these equa ¶ ₀ *(s) = U ₂ (s)/V ₁ (s) Then for steady states ¶ ₀ **= lim _{s→0} (s¶ ₀ *(s)) = U ₂ Where V ₁ (0) is specified in equal Mm ₀ = q ₀₁ Δ Mm ₁ + Mm ₁ = q ₁₀ Δ Mm ₀ -	Tim				$_3 \mathrm{Tp}_{3}^{\mathrm{o}}_{4}$	$+ Tp_{04}$	Γρ ₂₄)
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Nm 2 = q ₂₀ \triangle Nm 0 + Nm 3 = q ₃₀ \triangle Nm0 + 0 Nm 4=q ₄₅ \triangle Nm0 + q Nm 5 = q ₅₀ \triangle Nm0 + q Nm 6 = q ₆₀ \triangle Nm 0 + q Now solving these equa ¶0 [*] (s) = U ₂ (s)/V ₁ (s) Then for steady states ¶0 ^{**} = $\lim_{s\to 0} (s\P_0^*(s)) = U_2$ Where V ₁ (0) is specified in eq Paid Maintenance Tin The recursive relations Mm0 = q ₀₁ \triangle Mm1 + Mm 1 = q ₁₀ \triangle Mm 0 -	-		$2 + 01^{7}$	A Nn	$n_{4} + \tilde{N}$		
Nm 3 = q ₃₀ \triangle Nm ₀ + q Nm 4=q ₄₅ \triangle Nm ₅ +q ₄₆ \triangle Nm 5 = q ₅₀ \triangle Nm ₀ + q Nm 6 = q ₆₀ \triangle Nm 0 + q Now solving these equa ¶ ₀ *(s) = U ₂ (s)/V ₁ (s) Then for steady states ¶ ₀ **= lim (s¶ ₀ *(s)) = U ₂ Where V ₁ (0) is specified in eq Paid Maintenance Tin The recursive relations Mm ₀ = q ₀₁ \triangle Mm ₁ + Mm ₁ = q ₁₀ \triangle Mm ₀ -					.14 11		
Nm 4=q45 Δ Nm5+q46 Δ Nm 5 = q50 Δ Nm0 + q Nm 6 = q60 Δ Nm 0 + q Now solving these equa ¶0 [*] (s) = U ₂ (s)/V ₁ (s) Then for steady states ¶0 ^{**} = $\lim_{s\to 0} (s\P0^*(s)) = U_2$ Where V ₁ (0) is specified in eq Paid Maintenance Tin The recursive relations Mm0 = q01 Δ Mm1 + Mm 1 = q10 Δ Mm 0 -	-		-	1 111 4			
Nm 5 = q50 \triangle Nm ₀ + q Nm 6 = q60 \triangle Nm 0 + q Now solving these equations $\P_0^*(s) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s \P_0^*(s)) = U_2$ Where V ₁ (0) is specified in equations Paid Maintenance Tim The recursive relations Mm ₀ = q ₀₁ \triangle Mm ₁ + Mm ₁ = q ₁₀ \triangle Mm ₀ -	-			(10.11)			
Nm $_{6} = q_{60} \Delta Nm_{0} + q_{0}$ Now solving these equal $\P_{0}^{*}(s) = U_{2}(s)/V_{1}(s)$ Then for steady states $\P_{0}^{**} = \lim_{s \to 0} (s\P_{0}^{*}(s)) = U_{2}^{q}$ Where $V_{1}(0)$ is specified in equations Paid Maintenance Time The recursive relations $Mm_{0} = q_{01} \Delta Mm_{1} + Mm_{1} = q_{10} \Delta Mm_{0} - q_{0}$			³⁺ q ₄	· · · · 4)		114	
Now solving these equa $\P_0^*(s) = U_2(s)/V_1(s)$ Then for steady states $\P_0^{**} = \lim_{s \to 0} (s \P_0^*(s)) = U_2^{**}$ Where $V_1(0)$ is specified in equation Paid Maintenance Time The recursive relations $Mm_0 = q_{01} \Delta Mm_1 + Mm_1 = q_{10} \Delta Mm_0 - Mm_0$							
] 6 ⁽¹¹⁾ 4	⁴ Δ Nm		N N	1	11	
					_		function of t
Then for steady states	ation	s by tak	ing Lap	lace tra	instorm	and fir	ad \P_0 (s), we get
$ \P_0^{**} = \lim_{s \to 0} (s \P_0^{*}(s)) = U_2^{*} $ Where $ V_1(0) \text{ is specified in eq} $ Paid Maintenance Tim The recursive relations $ Mm_0 = q_{01} \Delta Mm_1 + Mm_1 = q_{10} \Delta Mm_0 - Mm_0 $							nd $\P_0^*(s)$, we get
Where $V_1(0)$ is specified in eq Paid Maintenance Tin The recursive relations $Mm_0 = q_{01} \Delta Mm_1 + Mm_1 = q_{10} \Delta Mm_0 - Mm_0$	с£						
$V_1(0)$ is specified in eq Paid Maintenance Tin The recursive relations $Mm_0 = q_{01} \Delta Mm_1 + Mm_1 = q_{10} \Delta Mm_0 - q_{01}$	(0) /	$V_1(0)$				-	
$V_1(0)$ is specified in eq Paid Maintenance Tin The recursive relations $Mm_0 = q_{01} \Delta Mm_1 + Mm_1 = q_{10} \Delta Mm_0 - q_{01}$		$U_{2}(0)$	= - Ñ T	b01(Tp	45 Tp50-	+ Tp ₄₆ T	$[\mathbf{p}_{60})$
Paid Maintenance Tin The recursive relations $Mm_0 = q_{01} \Delta Mm_1 + Mm_1 = q_{10} \Delta Mm_0 - Mm_0$	ı. (a).			r or (r	15 1 50	I 10	1 007
$\label{eq:main_state} \begin{array}{ll} The \ recursive \ relations \\ Mm_0 = q_{01} \ \Delta \ Mm_1 \ + \\ Mm_1 = q_{10} \ \Delta \ Mm_0 \ - \end{array}$	• • •						
$\begin{array}{llllllllllllllllllllllllllllllllllll$							
$Mm_1 = q_{10} \Delta Mm_0 -$		Λ Mm	2				
	-				lm ₄ + +	f	
$Mm_{0} - a_{0} \Lambda Mm_{0} \perp$						£	
$\begin{array}{ll} Mm_2 = q_{20} \ \Delta & Mm_0 + \\ Mm_3 = q_{30} \ \Delta & Mm_0 + \end{array}$				1	4		
$Mm_{3} = q_{30} \Delta Mm_{0} + Mm_{4} = q_{45} \Delta Mm_{5} + q_{46}$. (10,11)) ^ 1	1m	
				4` ′ 4) <u>Д</u> М	/11114	
$Mm_{5} = q_{50} \Delta Mm_{0} + \alpha$	-						
$Mm_{6} = q_{60} \Delta Mm_{0} +$		′4 Δ M1			1	11	
NT 1 1 1	q ₆ (11)				-		function of t
Now solving these equa $\dot{M}_0^*(s) = U_3(s)/V_1(s)$		s by taki	ing Lap	lace tra	instorm	n and fir	nd M_0 (s), we get

 $\dot{M}_{0}^{*}(s) = U_{3}(s)/V_{1}(s)$ Then for steady states $\dot{M}_{0}^{**} = \lim_{s \to 0} (s \dot{M}_{0}^{*}(s)) = U_{3}(0) / V_{1}(0)$

1

and

 $U_{3}(0) = - \pounds[Tp_{45}Tp_{50} + Tp_{46}Tp_{60}] [Tp_{01}Tp_{12}Tp_{23} + Tp_{04}Tp_{24}]$ V₁(0) is specified in eq. (a).

Minor Replacement Time

The recursive relations are $Mr_0 = q_{01} \Delta Mr_1 + q_{04} \Delta Mr_2$ $Mr_1 = q_{10} \Delta Mr_0 + q_{12} \Delta Mr_2 + q_1^7 \Delta Mr_4 +$ $Mr_2 = q_{20} \Delta Mr_0 + q_{23}\Delta Mr_3 + q_{24}\Delta Mr_4$ $Mr_3 = q_{30} \Delta Mr_0 + q_3^{8}_4 \Delta Mr_4 + m_1$ Mr $_{4}=q_{45} \Delta Mr_{5}+q_{46} \Delta Mr_{6}+(q_{4}^{(10,9)}+q_{4}^{(10,11)}) \Delta Mr_{4}$ $Mr_5 = q_{50} \Delta Mr_0 + q_5^{(9)}_4 \Delta Mr_4$ Mr $_{6} = q_{60} \Delta Mr_{0} + q_{6}^{(11)}_{4} \Delta Mr_{3}$ Here Mr_i , § and q_{kl} are all function of t Now solving these equations by taking Laplace transform and find $Ir_0^*(s)$, we get $Mr_0^*(t) = U_4(s) / V_1(s)$ $Mr_0^{**} = \lim_{s \to 0} (s Mr_0^{*}(s)) = U_4(0) / V_1(0)$ Where $U_4(0) = -Tp_{45} \$ [Tp_{01} Tp_{12} Tp_{23} Tp_{3}^{8} + Tp_{01} Tp_{12} Tp_{24} + Tp_{01} Tp_{1}^{(7)} - Tp_{04} Tp_{23} Tp_{3}^{(8)} + Tp_{04} Tp_{24})]$ and $V_1(0)$ is specified in eq. (a) **Major Replacement Time** The recursive relations are $M_{j_0} = q_{01} \Delta M_{j_1} + q_{04} \Delta M_{j_2}$ $M_{j_1} = q_{10} \Delta M_{j_0} + q_{12} \Delta M_{j_2} + q_{17}^{7} \Delta M_{j_4}$ JCR $M_{12} = q_{20} \Delta M_{10} + q_{23} \Delta M_{13} + q_{24} \Delta M_{14}$ $M_{j_3} = q_{30} \Delta M_{j_0} + q_{3}^{8}_{4} \Delta M_{j_4} + m_{1}^{8}_{4} \Delta M_{j_4}$ Mj 4=q45 Δ Mj5+q46 Δ Mj6 + (q4^(10,9)3+ q4^(10,11)4) Δ Mj4 $M_{j_{5}} = q_{50} \Delta M_{j_{0}} + q_{5}^{(9)} \Delta M_{j_{4}}$ $M_{j_{6}} = q_{60} \Delta M_{j_{0}} + q_{6}^{(11)} \Delta M_{j_{3}} + H_{0}$ Here Mj_i , m and q_{kl} are all function of t Now solving these equations by taking Laplace transform and find $\hat{R}_0^*(s)$, we get $M_{j_0}^{*}(t) = [U_5(s)/V_1(s)]$ $Mj_0^{**} = \lim_{s \to 0} (sMj_0^{*}(s))$ $= [U_5(0)/V_1(0)]$ Where $U_{5}(0) = H_{0} Tp_{46} [Tp_{01} Tp_{12} Tp_{23} Tp_{3}^{(8)} + Tp_{01} Tp_{12} Tp_{24} + Tp_{01} Tp_{1}^{(7)} + Tp_{04} Tp_{23} Tp_{3}^{(8)} + Tp_{04} Tp_{24} Tp_{24} + Tp_{12} Tp_{24} + Tp_{14} Tp_{14}$ And $V_1(0)$ is specified in eq. (a) **Inspection Time** The recursive relations are $IT_0 = q_{01} \Delta IT_1 + q_{04} \Delta IT_2$ $IT_1 = q_{10} \Delta IT_0 + q_{12} \Delta IT_2 + q_1^{7}_4 \Delta IT_4$ $IT_2 = q_{20} \Delta IT_0 + q_{23} \Delta IT_3 + q_{24} \Delta IT_4 + HK$ $IT_3 = q_{30} \Delta IT_0 + q_3^8 \Delta IT_4 + m$

 $IT_{4} = q_{45} \Delta IT_{5} + q_{46} \Delta Mj_{6} + (q_{4}^{(10,9)}_{3} + q_{4}^{(10,11)}_{4}) \Delta IT_{4}$

 $IT_5 = q_{50} \ \Delta \ IT_0 + q_5{}^{(9)}{}_4 \ \Delta \ IT_4$

$$\begin{split} & \Pi_{6} = q_{60} \ \Delta \ \Pi_{0} + q_{6}^{(11)_{4}} \ \Delta \ \Pi_{3} + H_{0} \\ & \text{Here IT}_{i} \text{, } \text{ix and } q_{k1} \text{ are all function of } t \\ & \text{Now solving these equations by taking Laplace transform and find } \hat{R}_{p0}^{*}(s) \text{, we get } \\ & \Pi_{0}^{*}(t) = U_{6}(s) / V_{1}(s) \\ & \text{In the unvarying state,} \\ & \Pi_{0}^{**} = \lim_{s \to 0} (s \ \Pi_{0}^{*}(s)) \\ & = U_{6}(0) / V_{1}^{*}(0) \\ & \text{Where} \\ & U_{6}(0) = - H_{X} (p_{01}p_{12} + p_{04}) (p_{45}p_{50} + p_{46}p_{60}) \\ & \text{And} \\ & M_{1}^{*}(t) = U_{1}^{*}(t) = U_{1}^{*}(t) \\ & \text{Where} \\ & U_{6}(t) = -H_{X} (p_{01}p_{12} + p_{04}) (p_{45}p_{50} + p_{46}p_{60}) \\ & \text{And} \\ & M_{1}^{*}(t) = U_{1}^{*}(t) \\ & \text{Here} \\ & U_{1}^{*}(t) \\ & \text{Here} \\ & U_{2}^{*}(t) \\ & \text{Here} \\ & U_{1}^{*}(t) \\ & \text{Here} \\ & U_{2}^{*}(t) \\ & U_{2}^{*}($$

 $V_1(0)$ is specified in eq. (a)

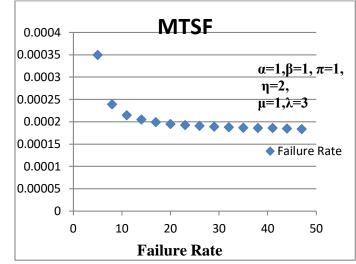
Busy Period of Repairman :-

Inspection Time + Normal Maintenance Time + Paid Maintenance Time + Minor Replacement Time + Major Replacement Time

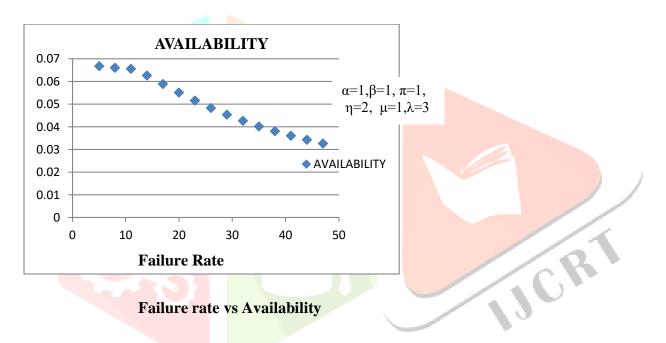
Particular cases:

If we take repair rate and inspection time as negative binomial distributions as

g(t)	=	$\theta e^{-\theta t}$; ;		m(t)	=	πe	-πt			
i(t)	=	$\delta e^{-\delta}$	t		n(t)	=	γe	-γt			
r ₁ (t)	=	μe ^{-μt}	+ ^		r ₂ (t)	=	pe				
k	=	α+λ			w	=	$\lambda + \gamma$	+δ			
	e	-	$\beta + \lambda + \gamma$			f	=	$\lambda + \rho$			
h	=	$\lambda + \pi$			j	=	$\lambda + \theta$		2		
Х	=	$\lambda + \mu$									
Then	we get,										
		Tp ₀₁	=	α/k			Tp ₀₄	ı =	λ/k		
		Tp ₁₀	=	γ/e			Tp ₁₂	2 =	β/e	2	
		Tp ₁₇	-	λ/e			Tp ₂₀) =	δ/w		
		Tp ₂₃	E .	γ / w			Tp ₂₄	=	λ / w	<u> </u>	
			=	π / h			Tp ₃₈	3 =	λ / h		
		$Tp_{1}^{7}_{4}$	=	λ / e			Tp ₃ ⁸	³ ₄ =	λ / h		
		Tp ₄₅	=	aθ/ j			Tp ₄₆	5 =	bθ / j		
		Tp _{4,10}	=	λ/j			Tp ₅₀) =	μ / x		
		Tp59	=	λ / x			Tp ₅ ⁹	° ₄ =	λ / x		
		Tp_{60}	=	ρ / f			Тр _{6,}	11 =	λ / f		
		μ_0	=	1 / k			μ_1	=	1/ e		
		μ_2	=	1/ w			μ_3	=	1/ h		
	μ_4	=	1/ j			μ_5	=	1/ x			
	μ_6	=	1/f								



Failure rate vs MTSF graph



CONCLUSION:

In this paper, a new conception of maintenance, repair and was taken together in system to avoid the loss of production and extensive damage for safety reasons. Also routine inspection concept also taken with these assumptions. By the particular cases, we conclude that

For the invariant value of $\alpha=1,\beta=1,\mu=1,\pi=1,\eta=2,\lambda=3$

MTSF goes on increases with the increase of failure rate.

Availability goes on decreases very sharply with the increases of failure rate.

Thus above conclusions help to get the desirable results in the field of design, development and production of individual production.

JCR

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