Tabular Comparison of Two similar Dual-unit Systems with single server

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***Abstract* — In this paper, reliability measures of two dual-unit systems having non-identical units are compared under different weather conditions namely normal & abnormal in steady state using semi-Markov process and regenerative point technique. In both the models, initially original unit (called as main unit) is operative while the other substandard unit (called as duplicate unit) is kept at cold standby mode. Two units either have normal mode of operation or failed. There is a single server who performs the repair activities of both units in normal weather conditions only. Server leaves the system in abnormal weather conditions. In model I, neither operation nor repair activities are allowed in abnormal weather conditions but in model II, operation of both units are allowed in different weather conditions. The distribution for failure times of the units and time to change of weather conditions are taken as negative exponential while that of repair time of the units are arbitrary. All random variables are statistically independent. The results for some important reliability measures such as MTSF, availability, busy period of server, expected number of visits by the server have been analyzed for arbitrary values of various parameters and costs. Reliability comparisons and profit comparisons are made between the two systems.**

***Index Terms* — Dual-unit system, Semi-Markov process, Regenerative point technique**

I. INTRODUCTION

In view of their frequent and vital use in management and industrial sectors, the repairable systems of two or more identical units have catered great attentiveness among researcher and scientists. These systems are investigated stochastically in detail by the scholars including Gopalan and Naidu (1982), Goyal and Murari (1984), and Singh (1989) under strict control of environment conditions. The weather environment has a significant impact on the performance of the operating systems. The physical stresses created by adverse weather conditions deteriorate performance and efficiency of these systems. Besides, scientists and engineers have tried a lot to develop systems which can work in varying environmental conditions but when cost of unit is higher than the non-identical unit (may be a substandard unit) might be kept as spare in cold standby not only to improve the reliability of the system but also to maintain performance of the system in emergency. Chander et al. (2007) discussed standby systems of non-identical units with different failure and repair policies. Each unit is capable of performing the same kind of functions but their degree of reliability and desirability may differ from unit to unit. The weather environment has a significant impact on the performance of the operating systems. The physical stresses created by adverse weather conditions deteriorate performance and efficiency of these systems. Also, sometimes it becomes very difficult to keep the environmental conditions under control which may fluctuate due changing climate and other natural catastrophic. While considering this fact in mind, Malik and Barak (2009), Malik et al. (2012) and Deswal. S (2015) obtained reliability and economic measures of a non-identical units with no operation and repair activities in abnormal weather.

This Paper concentrates on two repairable systems of two non-identical units. Both systems contain two units-one is original (called main unit) and other is a substandard unit (called duplicate unit) under two weather conditions – normal and abnormal. The environmental conditions when satisfied to the system correspond to normal weather; otherwise, it is supposed that the system is in abnormal weather. Initially, the system is operative with main unit and duplicate unit is kept a spare in cold standby. Both units have direct complete failure from normal mode. Each unit is capable of performing the same set of functions with different degree of reliability and desirability. There is a single server who visits the system immediately whenever needed to do repair of the failed unit in normal weather only. The operation and repair of the units are not allowed in abnormal weather as a precautionary measure to avoid excessive damage to the system in Model I. But sometimes we may have emergency situations in which operation of the system becomes necessary irrespective of weather conditions. Dhillon and Nateson (1983), Pawar et al. (2010, 2013), Promila et al. (2010) have determined reliability measures of a single unit system subject to weather conditions allowing operation in abnormal weather So, operation of both units is allowed in Model II .The repair of the units are as usual in normal weather. The units work as new after repair. In these Models repair activities are not allowed in abnormal weather. The distribution of failure times of units and change of weather conditions are taken as negative exponential while that of repair times of the units follow arbitrary distributions. All random variables are statistically independent. The semi-Markov and regenerative point technique are adopted to drive the expressions for the reliability measures such as mean time to system failure (MTSF), availability, busy period of the server, expected number of visits by the server and profit function. The results are analyzed through graphs for particular values of various parameters and costs. The mean time to system failure (MTSF) and profit of these Models are compared. The application of the present work can be visualized in a software industry where application software is run through two different databases-one is initially operative and other is kept in cold standby

II. NOTATIONS

E	The set of regenerative states
MO/DO	Main/Duplicate unit is good and operative
$\overline{MWO}$ / $\overline{DWO}$	Main/Duplicate unit is good and waiting for operation in abnormal weather
$\overline{MO}$ / $\overline{DO}$	Main/Duplicate unit is good and operating in abnormal weather
MCs/DCs	Main/Duplicate unit is in cold standby mode
$\overline{MCs}$ / $\overline{DCs}$	Main/Duplicate unit is in cold standby mode in abnormal weather
$\lambda/\ \lambda_1$	Constant failure rate of Main /Duplicate unit
$\beta/\ \beta_1$	Constant rate of change of weather from normal to abnormal/abnormal to normal weather
MFur/DFur	Main/duplicate unit failed and under repair
MFUR/DFUR	Main/duplicate unit failed and under repair continuously from previous state
MFwr/DFwr	Main/duplicate unit failed and waiting for repair
MFWR/DFWR	Main/duplicate unit failed and waiting for repair continuously from previous state
$\overline{MFwr}$ / $\overline{DFwr}$	Main/Duplicate unit failed and waiting for repair due to abnormal weather
$\overline{MFWR}$ / $\overline{DFWR}$	Main/Duplicate unit failed and waiting for repair continuously from previous state due to abnormal weather
g(t)/G(t)	pdf/cdf of repair time of Main unit
$g_1(t)/\ G_1(t)$	pdf/cdf of repair time of Duplicate unit
$q_{ij}\ (t)/Q_{ij}\ (t)$	pdf/cdf of passage time from regenerative state i to regenerative state j or to a failed state j without visiting any other regenerative state in (0,t]
$q_{ij.kr}\ (t)/\ Q_{ij.kr}\ (t)$	pdf/cdf of direct transition time from regenerative state i to a regenerative state j or to a failed state j visiting state k,r once in (0,t]
$q_{ij.k,(r,s)}{}^{n}(t)/Q_{ij.k,(r,s)}{}^{n}(t)$	pdf/cdf of direct transition time from regenerative state i to a regenerative state j or to a failed state j visiting state k once and n times states r and s.
$M_i(t)$	Probability that the system is up initially in regenerative state Si at time t without visiting to any other regenerative state
$W_i(t)$	Probability that the server is busy in state Siupto time t without making any transition to any other regenerative state or returning to the same via one or more non-regenerative states
m_{ij}	The conditional mean sojourn time in regenerative state Si when system is to make transition in to regenerative state Sj. Mathematically, it can be written as $$m_{ij} = E(T_{ij}) = \int_0^\infty t d[Q_{ij}(t)] = -q_{ij}^{*'}(0),$$ where T_{ij} is the transition time from state Si to Sj; Si, Sj ε E.
μ_i	The mean Sojourn time in state Si this is given by $$\mu_i = E(T_i) = \int_0^\infty P(T_i > t)dt = \sum_j m_{ij},$$ where T_i is the sojourn time in state Si.
Ⓢ/©/©^{n}	Symbol for Laplace Stieltjes convolution/Laplace convolution/Laplace convolution n times
** / *	Symbol for Laplace Steiltjes Transform (L.S.T.)/ Laplace transform (L.T.)
´(desh)	Used to represent alternative result

(Model 1)

The following are the possible transition states of the system**:**

S_0 = (MO, DCs), S_1 = (MFur, DO), $S_2 = (\overline{MWO}, \overline{DCs})$, $S_3 = (\overline{MFwr}, \overline{DWO})$,

S_4= (MFUR, DFwr), S_5= (MCs, DO), S_6= (MO, DFur), $S_7 = (\overline{MFwr}, \overline{DFWR})$,

S_8=(MFur,DFWR),$S_9 = (\overline{MCs}, \overline{DWO})$,$S_{10} = (\overline{MWO}, \overline{DFwr})$,

S_{11}=(MFwr,DFUR) , $S_{12} = (\overline{MFWR}, \overline{DFwr})$,S_{13}=(MFWR,DFur)

The states S_0, S_1, S_2, S_3, S_5, S_6, S_9 and S_{10} are regenerative while the states S_4, S_7, S_8, S_{11}, S_{12} and S_{13} are non-regenerative as shown in figure

State Transition Diagram

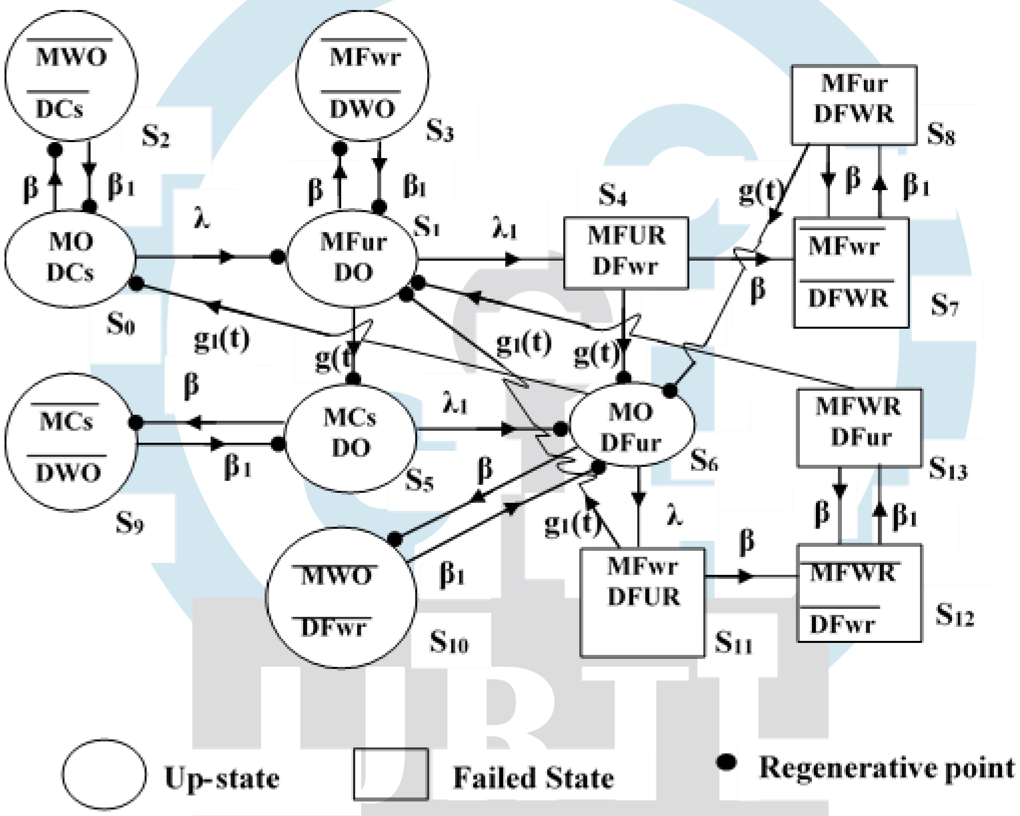

Fig.1

(Model2)

The following are the possible transition states of the system

S_0 = (MO, DCs), S_1 = (MFur, DO), $S_2 = (\overline{MO}, \overline{DCs})$, $S_3 = (\overline{MFwr}, \overline{DO})$,

S_4= (MFUR, DFwr), S_5= (MCs, DO), $S_6 = (\overline{MFWR}, \overline{DFwr})$, S_7= (MO, DFur),

$S_8 = (\overline{MFwr}, \overline{DFWR})$, S_9= (MFur, DFWR), $S_{10} = (\overline{MCs}, \overline{DO})$,

S_{11}= (MFwr, DFUR), $S_{12} = (\overline{MO}, \overline{DFwr})$

The states S_0, S_1, S_2, S_3, S_5, S_7, S_{10} and S_{12} are regenerative while the states S_4, S_6, S_8, S_9 and S_{11} are non-regenerative as shown in figure 2

State Transition Diagram

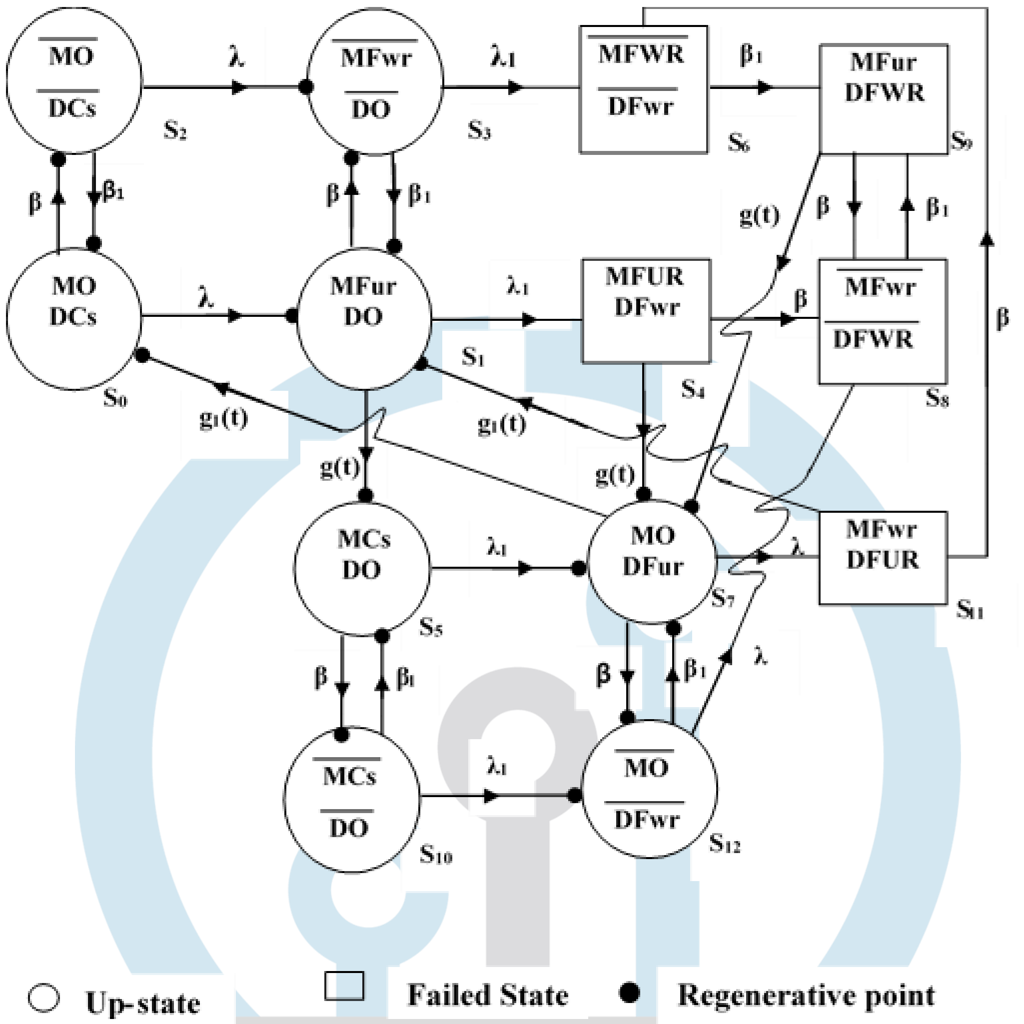

Fig. 2

III. RELIABILITY AND MEAN TIME TO SYSTEM FAILURE (MTSF)

Let $\emptyset_i(t)$ be the cdf of first passage time from regenerative state S_i to a failed state. Regarding the failed state as absorbing state, we have the following recursive relations for $\emptyset_i(t)$:

Model I:

$\emptyset_0(t) = Q_{01}(t)Ⓢ\emptyset_1(t) + Q_{02}(t)Ⓢ\emptyset_2(t)$

$\emptyset_1(t) = Q_{13}(t)Ⓢ\emptyset_3(t) + Q_{15}(t)Ⓢ\emptyset_5(t) + Q_{14}(t)$

$\emptyset_2(t) = Q_{20}(t)Ⓢ\emptyset_0(t); \emptyset_3(t) = Q_{31}(t)Ⓢ\emptyset_1(t)$

$\emptyset_5(t) = Q_{56}(t)Ⓢ\emptyset_6(t) + Q_{59}(t)Ⓢ\emptyset_9(t)$

$\emptyset_6(t) = Q_{60}(t)Ⓢ\emptyset_0(t) + Q_{6,10}(t)Ⓢ\emptyset_{10}(t) + Q_{6,11}(t)$

$\emptyset_9(t) = Q_{95}(t)Ⓢ\emptyset_5(t);\emptyset_{10}(t) = Q_{10,6}(t)Ⓢ\emptyset_6(t)$

Model II:

$\emptyset_0(t) = Q_{01}(t)Ⓢ\emptyset_1(t) + Q_{02}(t)Ⓢ\emptyset_2(t)$

$\emptyset_1(t) = Q_{13}(t)Ⓢ\emptyset_3(t) + Q_{15}(t)Ⓢ\emptyset_5(t) + Q_{14}(t)$

$\emptyset_2(t) = Q_{20}(t)Ⓢ\emptyset_0(t) + Q_{23}(t)Ⓢ\emptyset_3(t); \emptyset_3(t) = Q_{31}(t)Ⓢ\emptyset_1(t) + Q_{36}(t)$

$\emptyset_5(t) = Q_{57}(t)Ⓢ\emptyset_7(t) + Q_{5,10}(t)Ⓢ\emptyset_{10}(t)$

$\emptyset_7(t) = Q_{70}(t)Ⓢ\emptyset_0(t) + Q_{7,12}(t)Ⓢ\emptyset_{12}(t) + Q_{7,11}(t)$

$\emptyset_{10}(t) = Q_{10,5}(t)Ⓢ\emptyset_5(t) + Q_{10,12}(t)Ⓢ\emptyset_{12}(t); \emptyset_{12}(t) = Q_{12,7}(t)Ⓢ\emptyset_7(t) + Q_{12,8}(t)$

Taking L.S.T. of above relations and solving for $\emptyset_0^{**}(s)$, we get

we have

$$R^*(s) = \frac{1-\phi_0^{**}(s)}{s}$$

The reliability of the system can be obtained by taking inverse Laplace transform

The mean time to system failure (MTSF) is given by (Model I & Model II)

$$MTSF = \lim_{s\to 0}\frac{1-\phi_0^{**}(s)}{s} = \frac{N_1}{D_1}$$

IV. STEADY STATE AVAILABILITY

Let $A_i(t)$ be the probability that the system is in up-state at instant 't' given that the system entered regenerative state S_i at t=0. The recursive relations for $A_i(t)$ are given as:

(Model I)

$A_0(t) = M_0(t) + q_{01}(t) © A_1(t) + q_{02}(t) © A_2(t)$

$A_1(t) = M_1(t) + q_{13}(t)©A_3(t) + q_{15}(t) © A_5(t) + (q_{16.4}(t) + q_{16.4,(7,8)}^{n}(t)) ©A_6(t)$

$A_2(t) = q_{20}(t)©A_0(t); A_3(t) = q_{31}(t)©A_1(t)$

$A_5(t) = M_5(t) + q_{56}(t)©A_6(t) + q_{59}(t)©A_9(t)$

$A_6(t) = M_6(t) + q_{60}(t)©A_0(t) + (q_{61.11}(t) + q_{61.11(12,13)}^{n}(t))©A_1(t) + q_{6,10}(t)©A_{10}(t)$

$A_9(t) = q_{95}(t)©A_5(t); A_{10}(t) = q_{10,6}(t)©A_6(t)$

where $M_i(t)$ is the probability that the system is up initially in state $S_i \in E$ is up at time t without visiting to any other regenerative state, we have

$M_0(t)=e^{-(\beta+\lambda)t}$, $M_1(t)=e^{-(\beta+\lambda_1)t}\,\overline{G(t)}$, $M_5(t)= e^{-(\beta+\lambda_1)t}$, $M_6(t)= e^{-(\beta+\lambda)t}\,\overline{G_1(t)}$

(Model II)

$A_0(t) = M_0(t) + q_{01}(t) © A_1(t) + q_{02}(t) © A_2(t)$

$A_1(t) = M_1(t) + q_{13}(t)©A_3(t) + q_{15}(t) © A_5(t) + (q_{17.4}(t) + q_{17.4,(8,9)}^{n}(t)) ©A_7(t)$

$A_2(t) = M_2(t) + q_{20}(t)©A_0(t) + q_{23}(t)©A_3(t)$

$A_3(t) = M_3(t) + q_{31}(t)©A_1(t) + (q_{37.69}(t) + q_{37.6,(9,8)}^{n}(t))©A_7(t)$

$A_5(t) = M_5(t) + q_{57}(t)©A_7(t) + q_{5,10}(t)©A_{10}(t)$

$A_7(t) = M_7(t) + q_{70}(t)©A_0(t) + q_{71.11}(t)©A_1(t) + (q_{77.11,6,9}(t) + q_{77.11,6,(9,8)}^{n}(t))©A_7(t) + q_{7,12}(t)©A_{12}(t)$

$A_{10}(t) = M_{10}(t) + q_{10,5}(t)©A_5(t) + q_{10,12}(t)©A_{12}(t); A_{12}(t) = M_{12}(t) + (q_{12,7}(t) + q_{12,7.(8,9)}^{n}(t))©A_7(t)$

where $M_i(t)$ is the probability that the system is up initially in state $S_i \in E$ is up at time t without visiting to any other regenerative state, we have

$M_0(t)=e^{-(\beta+\lambda)t}$, $M_1(t)=e^{-(\beta+\lambda_1)t}\,\overline{G(t)}$, $M_2(t)=e^{-(\beta_1+\lambda)t}$, $M_3(t) = e^{-(\beta_1+\lambda_1)t}$, $M_5(t)=e^{-(\beta+\lambda_1)t}$,

$M_7(t)=e^{-(\beta+\lambda)t}\,\overline{G_1(t)}$, $M_{10}(t)=e^{-(\beta_1+\lambda_1)t}$, $M_{12}(t)=e^{-(\beta_1+\lambda)t}$

Taking L.T. of above relations and solving for $A_0^*(s)$, the steady state availability is given by

$$A_0(\infty) = \lim_{s\to 0} sA_0^*(s) = \frac{N_2}{D_2}$$

V. BUSY PERIOD ANALYSIS

Let $B_i(t)$ be the probability that the server is busy in repairing the unit at an instant 't' given that the system entered regenerative state S_i at t=0.The recursive relations for $B_i(t)$ are as follows:

(MODEL I)

$B_0(t) = q_{01}(t) © B_1(t) + q_{02}(t) © B_2(t)$

$B_1(t) = W_1(t) + q_{13}(t)©B_3(t) + q_{15}(t) © B_5(t) + (q_{16.4}(t) + q_{16.4,(7,8)}^{n}(t)) ©B_6(t)$

$B_2(t) = q_{20}(t)©B_0(t); B_3(t) = q_{31}(t)©B_1(t); B_5(t) = q_{56}(t)©B_6(t) + q_{59}(t)©B_9(t)$

$B_6(t) = W_6(t) + q_{60}(t)©B_0(t) + (q_{61.11}(t) + q_{61.11,(12,13)}^{n}(t))©B_1(t) + q_{6,10}(t)©B_{10}(t)$

$B_9(t) = q_{95}(t)©B_5(t); B_{10}(t) = q_{10,6}(t)©B_6(t)$

where $W_i(t)$ be the probability that the server is busy in state S_i due to failure up to time without making any transition to any other regenerative state or returning to the same via one or more non regenerative states so,

$W_1(t)=e^{-(\beta+\lambda_1)t}\,\overline{G(t)}+(\lambda_1 e^{-(\beta+\lambda_1)t} \copyright 1)\,\overline{G(t)}$, $W_6(t)=e^{-(\beta+\lambda)t}\,\overline{G_1(t)}+(\lambda e^{-(\beta+\lambda)t} \copyright 1)\,\overline{G_1(t)}$

(MODEL II)

$B_0(t)=q_{01}(t) \copyright B_1(t)+q_{02}(t) \copyright B_2(t)$

$B_1(t)=W_1(t)+q_{13}(t) \copyright B_3(t)+q_{15}(t) \copyright B_5(t)+(q_{17.4}(t)+q_{17.4,(8,9)}{}^n(t)) \copyright B_7(t)$

$B_2(t)=q_{20}(t) \copyright B_0(t)+q_{23}(t) \copyright B_3(t)$;

$B_3(t)=q_{31}(t) \copyright B_1(t)+(q_{37.69}(t)+q_{37.6,(9,8)}{}^n(t)) \copyright B_7(t)$

$B_5(t)=q_{57}(t) \copyright B_7(t)+q_{5,10}(t) \copyright B_{10}(t)$

$B_7(t)=W_7(t)+q_{70}(t) \copyright B_0(t)+q_{71.11}(t) \copyright B_1(t)+(q_{77.11,6,9}(t)+q_{77.11,6,(9,8)}{}^n(t)) \copyright B_7(t)+q_{7,12}(t) \copyright B_{12}(t)$

$B_{10}(t)=q_{10,5}(t) \copyright B_5(t)+q_{10,12}(t) \copyright B_{12}(t)$; $B_{12}(t)=(q_{12,7}(t)+q_{12,7.(8,9)}{}^n(t)) \copyright B_7(t)$

where

$W_1(t)=e^{-(\beta+\lambda_1)t}\,\overline{G(t)}+(\lambda_1 e^{-(\beta+\lambda_1)t} \copyright 1)\,\overline{G(t)}$, $W_7(t)=e^{-(\beta+\lambda)t}\,\overline{G_1(t)}+(\lambda e^{-(\beta+\lambda)t} \copyright 1)\,\overline{G_1(t)}$

Taking L.T. of above relations and solving for $B_0^*(s)$,we obtain

The time for which server is busy due to repair is given by

$$B_0^*(\infty)=\lim_{s\to 0} sB_0^*(s)=\frac{N_3}{D_2}$$

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VI. EXPECTED NUMBER OF VISITS BY THE SERVER

Let $N_i(t)$ be the expected number of visits by the server in (0,t] given that the system entered the regenerative state S_i at t=0. The recursive relations for $N_i(t)$ are given as

(MODEL I)

$N_0(t)=Q_{01}(t) \circledS (1+N_1(t))+Q_{02}(t) \circledS N_2(t)$

$N_1(t)=Q_{13}(t) \circledS N_3(t)+Q_{15}(t) \circledS N_5(t)+Q_{16.4}(t) \circledS N_6(t)+Q_{16.4,(7,8)}{}^n(t)) \circledS (1+N_6(t))$

$N_2(t)=Q_{20}(t) \circledS N_0(t)$; $N_3(t)=Q_{31}(t) \circledS (1+N_1(t))$

$N_5(t)=Q_{56}(t) \circledS (1+N_6(t))+Q_{59}(t) \circledS N_9(t)$

$N_6(t)=Q_{60}(t) \circledS N_0(t)+Q_{61.11}(t) \circledS N_1(t)+Q_{61.11,(12,13)}{}^n(t) \circledS (1+N_1(t))+Q_{6,10}(t) \circledS N_{10}(t)$

$N_9(t)=Q_{95}(t) \circledS N_5(t)$; $N_{10}(t)=Q_{10,6}(t) \circledS (1+N_6(t))$

(MODEL II)

$N_0(t)=Q_{01}(t) \circledS (1+N_1(t))+Q_{02}(t) \circledS N_2(t)$

$N_1(t)=Q_{13}(t) \circledS N_3(t)+Q_{15}(t) \circledS N_5(t)+Q_{17.4}(t) \circledS N_7(t)+Q_{17.4,(8,9)}{}^n(t) \circledS (1+N_7(t))$

$N_2(t)=Q_{20}(t) \circledS N_0(t)+Q_{23}(t) \circledS N_3(t)$; $N_3(t)=Q_{31}(t) \circledS (1+N_1(t))+(Q_{37.69}(t)+Q_{37.6,(9,8)}{}^n(t)) \circledS (1+N_7(t))$

$N_5(t)=Q_{57}(t) \circledS (1+N_7(t))+Q_{5,10}(t) \circledS N_{10}(t)$

$N_7(t)=Q_{70}(t) \circledS N_0(t)+Q_{71.11}(t) \circledS N_1(t)+(Q_{77.11,6,9}(t)+Q_{77.11,6,(9,8)}{}^n(t)) \circledS (1+N_7(t))+Q_{7,12}(t) \circledS N_{12}(t)$

$N_{10}(t)=Q_{10,5}(t) \circledS N_5(t)+Q_{10,12}(t) \circledS N_{12}(t)$; $N_{12}(t)=(Q_{12,7}(t)+Q_{12,7.(8,9)}{}^n(t)) \circledS (1+N_7(t))$

VII. PROFIT ANALYSIS

The profit incurred to the system model in steady state can be obtained as

$P=K_0A_0-K_1B_0-K_2N_0$;

K_0=Revenue per unit up-time of the system

K_1=Cost per unit for which server is busy

K_2= Cost per unit visit by the server and A_0, B_0, N_0 are already defined

MTSF (T_0) = $\frac{N_1}{D_1}$, Steady state availability (A_0) = $\frac{N_2}{D_2}$, Busy period of the server (B_0) = $\frac{N_3}{D_2}$, Expected number of visits by the server (N_0) = $\frac{N_4}{D_2}$

VIII. PARTICULAR CASES (MODEL I)

Simple probabilistic considerations yield the following expressions for the non-zero elements $p_{ij} = Q_{ij}(\infty) = \int_0^\infty q_{ij}(t)dt$ by taking all the distribution exponentially

(Suppose $g(t)=\alpha e^{-\alpha t}$, $g_1(t)=\alpha_1 e^{-\alpha_1 t}$)

$p_{01}=\frac{\lambda}{\beta+\lambda}$, $p_{02}=\frac{\beta}{\beta+\lambda}$, $p_{13}=\frac{\beta}{\alpha+\beta+\lambda_1}$, $p_{14}=\frac{\lambda_1}{\alpha+\beta+\lambda_1}$, $p_{15}=\frac{\alpha}{\alpha+\beta+\lambda_1}$, $p_{20}=1$, $p_{31}=1$,

$p_{46}=\frac{\alpha}{\alpha+\beta}$, $p_{47}=\frac{\beta}{\alpha+\beta}$, $p_{56}=\frac{\lambda_1}{\beta+\lambda_1}$, $p_{59}=\frac{\beta}{\beta+\lambda_1}$, $p_{60}=\frac{\alpha_1}{\alpha_1+\beta+\lambda}$, $p_{6,10}=\frac{\beta}{\alpha_1+\beta+\lambda}$,

$p_{6,11}=\frac{\lambda}{\alpha_1+\beta+\lambda}$, $p_{78}=1$, $p_{86}=\frac{\alpha}{\alpha+\beta}$, $p_{87}=\frac{\beta}{\alpha+\beta}$, $p_{95}=1$, $p_{10,6}=1$, $p_{11,1}=\frac{\alpha_1}{\alpha_1+\beta}$,

$p_{11,12}=\frac{\beta}{\alpha_1+\beta}$, $p_{12,13}=1$, $p_{13,1}=\frac{\alpha_1}{\alpha_1+\beta}$, $p_{13,12}=\frac{\beta}{\alpha_1+\beta}$, $p_{16.4}=\frac{\lambda_1}{\alpha+\beta+\lambda_1}\frac{\alpha}{\alpha+\beta}$

$p_{16.4(7,8)}^{n}=\frac{\lambda_1}{\alpha+\beta+\lambda_1}\frac{\beta}{\alpha+\beta}$, $p_{61.11}=\frac{\lambda}{\alpha_1+\beta+\lambda}\frac{\alpha_1}{\alpha_1+\beta}$, $p_{61.11,(12,13)}^{n}=\frac{\lambda}{\alpha_1+\beta+\lambda}\frac{\beta}{\alpha_1+\beta}$

$\mu_0=\frac{1}{\beta+\lambda}$, $\mu_1=\frac{1}{\alpha+\beta+\lambda_1}$, $\mu_2=\frac{1}{\beta_1}$, $\mu_3=\frac{1}{\beta_1}$, $\mu_4=\frac{1}{\alpha+\beta}$, $\mu_5=\frac{1}{\beta+\lambda_1}$, $\mu_6=\frac{1}{\alpha_1+\beta+\lambda}$,

$\mu_7=\frac{1}{\beta_1}$, $\mu_8=\frac{1}{\alpha+\beta}$, $\mu_9=\frac{1}{\beta_1}$, $\mu_{10}=\frac{1}{\beta_1}$, $\mu_{11}=\frac{1}{\alpha_1+\beta}$, $\mu_{12}=\frac{1}{\beta_1}$, $\mu_{13}=\frac{1}{\alpha_1+\beta}$

$\mu_1'=\frac{\alpha\beta_1+\beta\lambda_1+\beta_1\lambda_1}{\alpha\beta_1(\alpha+\beta+\lambda_1)}$, $\mu_6'=\frac{\alpha_1\beta_1+\beta\lambda+\beta_1\lambda}{\alpha_1\beta_1(\alpha_1+\beta+\lambda)}$; $W^*_1(0)=\frac{(\alpha+\lambda_1)}{\alpha(\alpha+\beta+\lambda_1)}$, $W^*_6(0)=\frac{(\alpha_1+\lambda)}{\alpha_1(\alpha_1+\beta+\lambda)}$

where

$N_1=(\beta+\beta_1)(\lambda_1(\alpha_1+\lambda)(\alpha+\lambda+\lambda_1)+\alpha\lambda(\alpha_1+\lambda+\lambda_1))$

$D_1=\lambda\lambda_1\beta_1(\alpha\lambda+\lambda_1(\alpha_1+\lambda))$

$N_2=\alpha\alpha_1\beta_1(\alpha+\lambda_1)(\lambda_1+\lambda)(\alpha_1+\lambda))$

$D_2=\alpha\lambda_1(\alpha+\lambda_1)(\alpha_1^2\beta_1+\lambda(\alpha_1\beta_1+\beta\lambda+\beta_1\lambda))+\alpha_1\lambda(\alpha_1+\lambda)(\lambda_1(\alpha\beta_1+\beta\lambda_1+\beta_1\lambda_1)+\alpha^2\beta_1)$

$N_3=\lambda\lambda_1\beta_1(\alpha+\lambda_1)(\alpha_1+\lambda)(\alpha+\alpha_1)$

$N_4=\frac{\alpha\alpha_1\beta_1\lambda\lambda_1((\alpha_1+\lambda)(\alpha_1+\beta)((\alpha+\beta)(2\alpha+\beta+\lambda_1)-\beta\lambda_1)-\lambda\alpha_1(\alpha+\lambda_1)(\alpha+\beta))}{(\alpha+\beta)(\alpha_1+\beta)}$

IX. PARTICULAR CASES (MODEL II)

Simple probabilistic considerations yield the following expressions for the non-zero elements

$p_{ij} = Q_{ij}(\infty) = \int_0^\infty q_{ij}(t)dt$

Suppose $g(t)=\alpha e^{-\alpha t}$, $g_1(t)=\alpha_1 e^{-\alpha_1 t}$

$p_{01}=\frac{\lambda}{\beta+\lambda}$, $p_{02}=\frac{\beta}{\beta+\lambda}$, $p_{13}=\frac{\beta}{\alpha+\beta+\lambda_1}$, $p_{14}=\frac{\lambda_1}{\alpha+\beta+\lambda_1}$, $p_{15}=\frac{\alpha}{\alpha+\beta+\lambda_1}$, $p_{20}=\frac{\beta_1}{\beta_1+\lambda}$,

$p_{23}=\frac{\lambda}{\beta_1+\lambda}$, $p_{31}=\frac{\beta_1}{\beta_1+\lambda_1}$, $p_{36}=\frac{\lambda_1}{\beta_1+\lambda_1}$, $p_{47}=\frac{\alpha}{\alpha+\beta}$, $p_{48}=\frac{\beta}{\alpha+\beta}$, $p_{57}=\frac{\lambda_1}{\beta+\lambda_1}$, $p_{5,10}=\frac{\beta}{\beta+\lambda_1}$, $p_{69}=1$,

$p_{70}=\frac{\alpha_1}{\alpha_1+\beta+\lambda}$, $p_{7,11}=\frac{\lambda}{\alpha_1+\beta+\lambda}$, $p_{7,12}=\frac{\beta}{\alpha_1+\beta+\lambda}$, $p_{89}=1$, $p_{97}=\frac{\alpha}{\alpha+\beta}$,

$p_{98}=\frac{\beta}{\alpha+\beta}$,$p_{10,5}=\frac{\beta_1}{\beta_1+\lambda_1}$,$p_{10,12}=\frac{\lambda_1}{\beta_1+\lambda_1}$,$p_{11,1}=\frac{\alpha_1}{\alpha_1+\beta}$,$p_{11,6}=\frac{\beta}{\alpha_1+\beta}$,$p_{12,7}=\frac{\beta_1}{\beta_1+\lambda}$,$p_{12,8}=\frac{\lambda}{\beta_1+\lambda}$,$p_{17.4}=\frac{\lambda_1}{\alpha+\beta+\lambda_1}\frac{\alpha}{\alpha+\beta}$,$p_{17.4(8,9)}{}^{n}=\frac{\lambda_1}{\alpha+\beta+\lambda_1}\frac{\beta}{\alpha+\beta}$,$p_{37.69}=\frac{\lambda_1}{\beta_1+\lambda_1}\frac{\alpha}{\alpha+\beta}$, $p_{37.6(9,8)}{}^{n}=\frac{\lambda_1}{\beta_1+\lambda_1}\frac{\beta}{\alpha+\beta}$,$p_{71.11}=\frac{\lambda}{\alpha_1+\beta+\lambda}\frac{\alpha_1}{\alpha_1+\beta}$,$p_{77.11,6(9,8)}{}^{n}=\frac{\lambda}{\alpha_1+\beta+\lambda}\frac{\beta}{\alpha_1+\beta}$, $p_{12,7.(8,9)}{}^{n}=\frac{\lambda}{\beta_1+\lambda}$

$\mu_0=\frac{1}{\beta+\lambda}$,$\mu_1=\frac{1}{\alpha+\beta+\lambda_1}$,$\mu_2=\frac{1}{\beta_1+\lambda}$,$\mu_3=\frac{1}{\beta_1+\lambda_1}$,$\mu_4=\frac{1}{\alpha+\beta}$,$\mu_5=\frac{1}{\beta+\lambda_1}$,$\mu_6=\frac{1}{\beta_1}$,

$\mu_7=\frac{1}{\alpha_1+\beta+\lambda}$,$\mu_8=\frac{1}{\beta_1}$,$\mu_9=\frac{1}{\alpha+\beta}$,$\mu_{10}=\frac{1}{\beta_1+\lambda_1}$,$\mu_{11}=\frac{1}{\alpha_1+\beta}$,$\mu_{12}=\frac{1}{\beta_1+\lambda}$,

$\mu_1'=\frac{\alpha\beta_1+\lambda_1(\beta+\beta_1)}{\alpha\beta_1(\alpha+\beta+\lambda_1)}$, $\mu_3'=\frac{\alpha(\beta_1+\lambda_1)+\lambda_1(\beta+\beta_1)}{\alpha\beta_1(\beta_1+\lambda_1)}$, $\mu_7'=\frac{\alpha\beta_1(\alpha_1+\beta)+\lambda(\alpha+\beta)(\beta+\beta_1)}{\alpha\beta_1(\alpha_1+\beta)(\alpha_1+\beta+\lambda)}$,

$\mu_{12}'=\frac{\alpha\beta_1+\lambda(\alpha+\beta+\beta_1)}{\alpha\beta_1(\beta_1+\lambda)}$,$W^*_1(0)=\frac{(\alpha+\lambda_1)}{\alpha(\alpha+\beta+\lambda_1)}$, $W^*_7(0)=\frac{(\alpha_1+\lambda)}{\alpha_1(\alpha_1+\beta+\lambda)}$

$N_1 = A\lambda_1(\beta+\beta_1+\lambda_1)((\beta+\beta_1+\lambda)(E+\beta\lambda(1+C))+\alpha\beta\lambda((\beta+\beta_1+\lambda_1)A+\lambda_1B+\beta\lambda_1D)$

$D_1 = \lambda\lambda_1^2A(\beta+\beta_1+\lambda_1)(B+\beta C+\alpha\lambda\lambda_1B(\beta D+B))$

$N_2=\alpha\beta_1(\alpha_1\lambda_1(\beta+\beta_1+\lambda_1)(\beta_1+\lambda)(\alpha_1+\beta+\lambda)((\beta+\beta_1+\lambda)E+\lambda(B+\beta C)+\alpha\alpha_1\lambda\beta(B-\beta\beta_1)(\alpha_1+\beta+\lambda)+\alpha\alpha_1\beta\lambda^2\lambda_1(\beta(\beta_1+\lambda+\lambda_1)+(B-\beta\beta_1))+\lambda\lambda_1^2(\beta+\beta_1+\lambda_1)((\alpha_1+\beta)(\beta C+B)-\alpha_1(\beta+\beta_1+\lambda)(\beta+\beta_1+\lambda_1))(\beta_1+\lambda)+\alpha\alpha_1\lambda(\beta_1-\lambda_1)((\beta+\beta_1+\lambda)(\beta_1+\lambda_1)+\beta\lambda)(B-\beta\beta_1)+\beta\lambda\lambda_1^2(\beta_1+\lambda_1+\beta)(\alpha_1+\beta)(\beta C+B)+\alpha\lambda\lambda_1B(\beta+\beta_1+\lambda)(\alpha_1+\beta)(\beta_1+\lambda_1)+\alpha\beta\lambda B((\beta_1+\lambda)((\alpha_1+\beta)+\alpha_1(\alpha_1+\beta+\lambda))+(\alpha_1+\beta)^2+\alpha_1\lambda)\lambda_1))$

$D_2=\alpha_1\lambda_1(\beta_1+\lambda)(\alpha_1+\beta+\lambda)(\beta+\beta_1+\lambda_1)(\alpha\beta_1(\beta+\beta_1+\lambda)E)+\lambda(\alpha\beta_1+\lambda_1(\beta+\beta_1))B+\beta\lambda(\alpha(\beta_1+\lambda_1)+\lambda_1(\beta+\beta1))C+\alpha^2\alpha_1\lambda\beta_1(B-\beta\beta_1)(\alpha_1+\beta+\lambda)B+\alpha\alpha_1\beta\lambda^2\lambda_1(\alpha\beta_1(\beta_1+\lambda)(\beta+\beta_1+\lambda_1)+\beta\lambda_1(\alpha\beta_1+\lambda(\alpha+\beta+\beta_1)))+\lambda\lambda_1^2(\beta+\beta_1+\lambda_1)(\beta_1+\lambda)((\alpha\beta_1(\alpha_1+\beta+\lambda)+\beta\lambda(\alpha+\beta+\beta_1))(\beta C+B)-\alpha_1(\beta\beta_1(\beta+\beta_1)+\beta_1(\beta_1+\lambda_1)(\beta_1+\beta+\lambda)+\beta\lambda(\beta_1+\lambda_1)))$
$+\alpha\alpha_1\lambda(\beta-\lambda_1)(\alpha\beta_1(\beta_1+\lambda_1)(\beta+\beta_1+\lambda)+\beta\lambda(\alpha(\beta_1+\lambda_1)+\lambda_1(\beta+\beta_1)))(B-\beta\beta_1)+\beta\lambda\lambda_1^2(\alpha_1+\beta)(\beta+\beta_1+\lambda_1)(\alpha\beta_1+\lambda(\alpha+\beta+\beta_1)))(\beta C+B)+\alpha\lambda\lambda_1B((\alpha\beta_1(\alpha_1+\beta+\lambda)+\beta\lambda(\alpha+\beta+\beta_1))(\beta_1+\lambda)+\beta(\alpha\beta_1+\lambda(\alpha+\beta+\beta_1))(\alpha_1+\beta))(\beta_1+\lambda_1)+\alpha\beta\lambda B((\beta_1+\lambda)(\lambda_1(\alpha\beta_1(\alpha_1+\beta+\lambda)+\beta\lambda(\alpha+\beta+\beta_1))+\alpha\alpha_1\beta_1(\alpha_1+\beta+\lambda))+\lambda_1((\alpha_1+\beta)^2+\alpha_1\lambda)(\alpha\beta_1+\lambda(\alpha+\beta+\beta_1)))$

$$N_3=\frac{\begin{array}{l}\lambda\lambda_1\alpha_1^2(\alpha+\lambda_1)(\beta+\beta_1+\lambda_1)(B(\alpha_1+\beta+\lambda)+\lambda\lambda_1\beta)+\lambda(\alpha_1+\lambda)(\beta\lambda_1C+(\alpha+\lambda_1)B)\\ \alpha\beta_1(\alpha_1+\beta)(\beta+\lambda_1)(B-\beta\beta_1)\end{array}}{\alpha_1}$$

$$N_4=\frac{\begin{array}{l}\alpha\beta_1(\beta_1+\lambda)\lambda\lambda_1\alpha_1(\beta+\beta_1+\lambda_1)(E(\beta_1+\lambda)(\alpha+\beta)+\beta\lambda B+\beta(B-\beta\beta_1)C)\\ +\alpha\alpha_1\lambda\lambda_1B+\lambda_1^2\lambda^2\beta\alpha\alpha_1(\beta+\beta_1+\lambda_1)+\lambda_1(\beta+\beta_1+\lambda_1)(\beta\lambda\lambda_1(\alpha+\beta)(\beta(\beta_1+\lambda)C+\\ B\lambda)+\alpha_1\lambda^2\lambda_1(\beta^2\lambda_1-(\alpha+\beta)(\beta_1+\lambda_1)(\beta+\beta_1+\lambda)-\beta(\alpha+\beta)(\beta_1+\lambda)))+\alpha\alpha_1\lambda^2(\beta-\lambda_1)\\ (\beta+\beta_1+\lambda)+\alpha\beta\lambda\lambda_1(B(\lambda(\beta_1+\lambda_1)+(\alpha_1+\beta)D)+\beta\lambda\lambda_1^2(\beta+\beta_1+\lambda_1)(\beta C+B)))\end{array}}{(\alpha+\beta)}$$

$A=(\alpha_1+\lambda)(\beta_1+\lambda)+\beta\lambda$;
$B=(\beta_1+\lambda)(\beta_1+\lambda_1)+\beta\beta_1$;
$C=\alpha+\beta+\lambda+\beta_1+\lambda_1$;
$D=\alpha_1+\beta_1+\lambda_1+\beta+\lambda$
$E=(\alpha+\lambda_1)(\beta_1+\lambda_1)+\beta\lambda_1$

TABLES OF MODEL I

Table 1.1: MTSF vs. Normal Weather Rate (β_1)

Normal Weather Rate(β_1)	α=2,α_1=2.5, β=0.01, λ=0.5,λ_1=0.6	α=1.5	α_1=2	β=0.05	λ=0.3	λ_1=0.4
1.1	11.02792208	9.734759	10.42727	11.42532	16.99522	15.77851
1.2	11.01964286	9.727451	10.41944	11.38393	16.98246	15.76667
1.3	11.01263736	9.721267	10.41282	11.3489	16.97166	15.75664
1.4	11.00663265	9.715966	10.40714	11.31888	16.96241	15.74805
1.5	11.00142857	9.711373	10.40222	11.29286	16.95439	15.74061
1.6	10.996875	9.707353	10.39792	11.27009	16.94737	15.73409
1.7	10.99285714	9.703806	10.39412	11.25	16.94118	15.72834
1.8	10.98928571	9.700654	10.39074	11.23214	16.93567	15.72323
1.9	10.98609023	9.697833	10.38772	11.21617	16.93075	15.71866
2.0	10.98321429	9.695294	10.385	11.20179	16.92632	15.71455

Table 1.2: Availability vs. Normal Weather Rate (β_1)

Normal weather Rate (β_1)	α=2,α_1=2.5,β=0.01, λ=0.5,λ_1=0.6	α=1.5	α_1=2	β=0.05	λ=0.3	λ_1=0.4
1.1	0.952288701	0.93391	0.944042	0.950654	0.969052	0.967458
1.2	0.952322813	0.933956	0.944081	0.950824	0.969075	0.967482
1.3	0.952351679	0.933995	0.944115	0.950968	0.969094	0.967502
1.4	0.952376422	0.934029	0.944144	0.951091	0.96911	0.967519
1.5	0.952397867	0.934058	0.944169	0.951198	0.969124	0.967534
1.6	0.952416632	0.934083	0.94419	0.951292	0.969137	0.967547
1.7	0.952433191	0.934106	0.94421	0.951375	0.969148	0.967558
1.8	0.95244791	0.934126	0.944227	0.951448	0.969157	0.967569
1.9	0.95246108	0.934144	0.944242	0.951514	0.969166	0.967578
2	0.952472933	0.93416	0.944256	0.951573	0.969174	0.967586

Table 1.3: Profit vs. Normal weather rate (β_1)

Normal Weather Rate (β_1)	K_0=5000, K_1=350, K_2=300 α=2,α_1=2.5,β=0.01, λ=0.5,λ_1=0.6	α=1.5	α_1=2	β=0.05	λ=0.3	λ_1=0.4
1.1	4577.52164	4476.754344	4531.372	4564.752	4704.575	4693.31
1.2	4577.68561	4476.97648	4531.562	4565.568	4704.684	4693.425
1.3	4577.824362	4477.164458	4531.724	4566.259	4704.776	4693.522
1.4	4577.9433	4477.325595	4531.862	4566.851	4704.856	4693.605
1.5	4578.046384	4477.465256	4531.981	4567.365	4704.924	4693.677
1.6	4578.136586	4477.587467	4532.086	4567.814	4704.985	4693.74
1.7	4578.21618	4477.695306	4532.178	4568.211	4705.038	4693.796
1.8	4578.286932	4477.791167	4532.261	4568.563	4705.085	4693.845
1.9	4578.350238	4477.876941	4532.334	4568.879	4705.127	4693.89
2	4578.407215	4477.95414	4532.4	4569.163	4705.165	4693.929

X. CONCLUSION

To make the study more concrete, the numerical results giving particular values to the various parameters and cost are obtained to depict the behavior of Mean Time to System Failure (MTSF), availability and profit functions as shown respectively in table 1.1,1.2 and 1.3.. It is revealed that MTSF decreases with the increase in normal weather rate (β_1) and failure rates (λ, λ_1) of the units. And, it increases with increase of abnormal weather rate (β) and repair rates (α, α_1) of the units. The results show that availability and profit of the system model keep on increasing as normal weather rate (β_1) and repair rates (α, α_1) increase while their values decline with the increase of abnormal weather rate (β) and failure rates (λ, λ_1) of the units.

TABLES OF MODEL II

Table 2.1: MTSF vs. Normal Weather Rate (β_1)

Normal Weather Rate(β_1)	α=2,α_1=2.5, β=0.01, λ=0.5, λ_1=0.6	α=1.5	α_1=2	β=0.05	λ=0.3	λ_1=0.4
1.1	10.81265003	9.558699	10.23212	10.38711	16.63942	15.44215
1.2	10.82301836	9.566447	10.24109	10.43278	16.65879	15.46063
1.3	10.83189545	9.573089	10.24878	10.47227	16.67519	15.4763
1.4	10.83956277	9.578834	10.25542	10.50667	16.68922	15.48972
1.5	10.84623763	9.583842	10.26121	10.53686	16.70133	15.50132
1.6	10.85209002	9.588238	10.26628	10.5635	16.71186	15.51141
1.7	10.85725452	9.592123	10.27077	10.58715	16.7211	15.52027
1.8	10.86183891	9.595575	10.27475	10.60825	16.72924	15.52808
1.9	10.8659303	9.59866	10.2783	10.62718	16.73647	15.53502
2	10.86959981	9.601431	10.28149	10.64423	16.74292	15.54122

Table 2.2:Availability vs. Normal Weather Rate(β_1)

Normal weather rate(β_1)	α=2, α_1=2.5, β=0.01, λ=0.5, λ_1=0.6	α=1.5	α_1=2	β=0.05	λ=0.3	λ_1=0.4
1.1	0.950347	0.931773	0.942093	0.941157	0.967691	0.965912
1.2	0.950626	0.932071	0.942375	0.942497	0.967895	0.966142
1.3	0.95085	0.932311	0.9426	0.943574	0.968057	0.966325
1.4	0.951032	0.932507	0.942784	0.944454	0.968187	0.966472
1.5	0.951181	0.93267	0.942936	0.945182	0.968293	0.966593
1.6	0.951307	0.932806	0.943063	0.945792	0.968381	0.966694
1.7	0.951413	0.932922	0.94317	0.946309	0.968455	0.966778
1.8	0.951503	0.933022	0.943262	0.94675	0.968518	0.96685
1.9	0.95158	0.933108	0.943341	0.947132	0.968571	0.966912
2	0.951648	0.933183	0.94341	0.947463	0.968618	0.966965

Table 2.3:Profit vs. Normal Weather Rate (β_1)

Normal Weather Rate(β_1)	K_0=5000, K_1=350, K_2=300 α=2, α_1=2.5, β=0.01, λ=0.5, λ_1=0.6	α=1.5	α_1=2	β=0.05	λ=0.3	λ_1=0.4
1.1	4580.337	4478.358	4533.739	4551.665	4665.46	4618.913
1.2	4584.713	4482.662	4538.124	4562.637	4669.328	4625.877
1.3	4588.158	4486.011	4541.579	4570.333	4672.445	4631.583
1.4	4591.171	4488.935	4544.601	4576.817	4675.181	4636.593
1.5	4593.831	4491.515	4547.269	4582.352	4677.607	4641.03
1.6	4596.199	4493.809	4549.646	4587.128	4679.775	4644.988
1.7	4598.323	4495.864	4551.777	4591.29	4681.725	4648.542
1.8	4600.239	4497.717	4553.7	4594.949	4683.49	4651.753
1.9	4601.978	4499.397	4555.446	4598.19	4685.096	4654.668
2	4603.564	4500.928	4557.038	4601.081	4686.564	4657.326

XI. CONCLUSION

The graphs for MTSF, availability and profit function of the system are drawn for fixed values of the various parameters and costs as shown respectively in table2.1, 2.2 and2.3. These tables indicate that there is substantial positive change in these measures with increase of normal weather rate (β_1) and repair rates (α and α_1) of the units. While there values decline with increase of abnormal weather rate (β) and failure rates (λ and λ_1) of the units. However, the effect of repair rate of the main unit is more.

Table A: MTSF Difference of Model 1 and Model 2

Normal Weather Rate(β_1)	α=2,α_1=2.5,β=0.01, λ=0.5,λ_1=0.6	α=1.5	α_1=2	β=0.05	λ=0.3	λ_1=0.4
1.1	0.215272046	0.17606	0.19515	1.038217	0.3558	0.336366
1.2	0.196624495	0.161004	0.17835	0.951152	0.323667	0.306038
1.3	0.180741917	0.148178	0.16404	0.876633	0.296467	0.280342
1.4	0.167069882	0.137132	0.151721	0.812203	0.273184	0.258329
1.5	0.15519094	0.127531	0.141014	0.756001	0.253055	0.239288
1.6	0.144784984	0.119115	0.131633	0.706593	0.235504	0.222676
1.7	0.135602619	0.111684	0.123352	0.662853	0.22008	0.208073
1.8	0.127446805	0.105078	0.115995	0.62389	0.206432	0.195148
1.9	0.120159921	0.099172	0.109419	0.588986	0.194281	0.183637
2	0.113614472	0.093863	0.10351	0.557558	0.1834	0.173328

Table B: Profit Difference between Model 2 and Model 1

Normal Weather Rate(β_1)	K_0=5000,K_1=350, K_2=300 α=2,α_1=2.5,β=0.01, λ=0.5,λ_1=0.6	α=1.5	α_1=2	β=0.05	λ=0.3	λ_1=0.4
1.1	2.815333	1.603159	2.367313	-13.0868	-39.1152	-74.3969
1.2	7.027188	5.685338	6.561998	-2.93067	-35.356	-67.5478
1.3	10.33364	8.846064	9.855547	4.074209	-32.3319	-61.9388
1.4	13.22732	11.60966	12.73913	9.966247	-29.6745	-57.012
1.5	15.78423	14.04949	15.28801	14.98696	-27.3173	-52.6475
1.6	18.06224	16.22143	17.55956	19.31374	-25.21	-48.7524
1.7	20.10633	18.16885	19.59837	23.07956	-23.313	-45.2536
1.8	21.95202	19.92598	21.4397	26.38589	-21.5952	-42.0926
1.9	23.6278	21.52028	23.11183	29.31138	-20.0313	-39.222
2	25.1568	22.97404	24.63777	31.91789	-18.601	-36.6031

XII. COMPARATIVE STUDY

i. Comparison of MTSF (Between Model 1 and Model 2)

The MTSF of the system Model 1 is more than that of system Model 2.The MTSF difference (Model 1- Model 2) of these Models go on decreasing with increase of normal weather rate (β_1) and repair rates (α and α_1) of the units while it increases with increase of abnormal weather rate (β) and failure rates of the units as shown in Table A. Thus, a system of non-identical units would be more reliable to use in either of the following ways

- If it is not allowed to operate in abnormal weather
- If it is allowed to operate in abnormal weather, then by increasing repair rates of the failed units

ii. Comparison of Profit (Between Model 2 and Model 1)

The profit difference of the system Models is shown in Table B. The profit difference (Model 2-Model 1) goes on increasing with increase of normal weather rate (β_1), repair rates (α and α_1) and failure rates (λ and λ_1) of the units. But, it declines rapidly with the increase of abnormal weather rate (β). Thus, the study reveals that a system of non-identical units working in different weather conditions can be made more profitable by allowing its operation in abnormal weather with high repair rates of the failed units.

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