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Mathematical Modeling to Analyse the Reliability of the Cattle Feed Plant

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Abstract:
Modelling of the system and reliability analysis is the purpose of this paper, to analysis the reliability of cattle feed plant by exploitation Mathematica underneath expressed conditions. CAS Mathematica helps to analysed the reliability for different failure and repair rates in shorter time period along with probability of each state and also with accuracy so rectify the chances of error. The cattle feed plant consists of seven units which are arranged either in series or parallel combination. Two units failing through reduced state and remaining of five units failing directly. The model is regenerate into set of differential equations by exploitation chapman – Kolmogorov differential equations. These first order differential equations are then solved to analyse the reliability of system. Graphical analysis of reliability is additionally studied.

***Keywords:** Seven-unit system, Markov birth-death process, Chapman Kolmogorov Differential Equation, Mathematica, Steady state Reliability.*

1. Introduction:

In digital India, use of computer is not finite to bound field. Its explored in field of reliability conjointly. With the increasing demand of society of contemporary technologies, the reliability of system becomes major concern in recent years. Within the present paper, the reliability of cattle feed plant has been analysed by exploitation Mathematica so the current paper emphasizes the utilization of software (Mathematica) for analysis of reliability to reduce calculation work, to save lots of time and to provide accuracy in result. The given system has nine units within which there is just one operating state, three reduced state and remaining of the failed states. In our analysis of paper, we have got been done our calculation work for study of variation of reliability of each of its individual unit.

The feed industry has trendy computerized plants so to analysed the reliability to increase its production is main concern of the paper. In [1] Ombir Dahiya, Ashish Kumar and Monika Saini, have discussed the “Mathematical Modeling and Performance Evaluation of A-Pan Crystallization System in a Sugar Industry” for evaluation of performance of system after its modelling by chapman Kolmogorov differential equation. In [2] S M Rizwan, A G Mathew have discussed the “Performance Analysis of Port Cranes” to evaluate availability of the plant. In [3] Parveen Kumar and P.C. Tewari have discussed the “Performance analysis and optimization for CSDGB filling system of a beverage plant using particle swarm optimization” to optimize the performance of system.In [4] Anil Kr. Aggarwal, Sanjeev Kumar., Vikram Singh have discussed the “Performance Modelling and Availability Analysis of Skimmed Milk Powder Production System of a dairy Plant”. In [5] Tarun Kumar Garg, Reena Garg & Shalini Jindal have analysed the “Reliability Analysis of Ammonia Synthesis Unit in a Fertilizer Plant using CAS Mathematica”.

In [6] Deepika Garg, Kuldeep Kumar & Jai Singh discussed the “Availability analysis of cattle feed plant by using matrix method”. In present paper we

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will analyse the "Reliability of cattle feed plant by using Mathematica" So we take the System, its mathematical formulation and transition diagram from [6].

2. System Configuration, Notations and Assumptions:

The cattle feed plant consists of nine units: seven operative units and two standby units

(1) ***Unit A (Elevator)*****:** Raw material is lifted by elevator. The system failed directly on failure of the subsystem 'A'.

(2) ***Unit B (Grinder)***: Lifted material by elevator is place into the grinder for attrition. The system is also failed directly when the subsystem B fails.

(3) ***Unit C (Hopper)*****:** Hopper is used to cool down the grind material. In this case, System failed on failure of the hopper.

(4) ***Unit D (Mixer)*****:** Mixer mix the additives in fixed proportion into cooled grind material. Subsystem 'D' has standby support so failed through reduced state.

(5) ***Unit*** $\bar{D}$**:** In this unit, Mixer works in standby state and failed completely on failure of this unit.

(6) ***Unit E (Winch)*****:** In this unit, mixer is lifted by winch into palletiser. Also, system fails directly when the subsystem 'E' fails.

(7) ***Unit F (Palletiser)*****:** Palletiser shapes the mixer and consist of two subsystems, one working and another cold standby. Cold standby state becomes operative on failure of the working state. System fails only when both of subsystems fails.

(8) ***Unit*** $\bar{F}$**:** In this unit, Palletiser works in cold standby state. Cold standby state becomes operative on failure of the working state. System fails only when both of subsystems fails.

(9) ***Unit G (Screw Conveyor)*****:** Screw conveyor conveys the produced material to destination and System fails directly on failure of the subsystem 'G'.

Notations:

A, B, C, D, E, F, G: Represents the units in operative mode.
$\bar{D}, \bar{F}$ **:** Represents the units inreduced mode.
a, b, c, d, e, f, g : Represents the units in failed mode.

a_i**:** Represents the constant failure rates of Elevator, Grinder, Hopper, Mixer, Winch, Palletiser, Screwconveyor.
b_i**:** Representsthe constant failure rates of Elevator, Grinder, Hopper,Mixer, Winch, Palletiser, Screw conveyor.
$X_i(t)$ **:** Represents the probability of the ith state at time 't'.
$X_i'(t)$ **:** Represents the derivative of the probability function $P_i(t)$ w.r.t 't'.

Assumptions:

The failure and repair rates follow exponential distribution.
The Switch over devices are perfect as new one.The units D and F has standby support so failed through reduced states.

- More than one failure does not occur at a time.
- There is no simultaneous failure.

3. Mathematical Formulation of the Model:

The mathematical modelling of the system is carried out to determine the reliability of cattle feed plant and Chapman-Kolmogorov differential equations are developed on the basis of Markov birth-death process by using transition dig. taken from paper [6]. The following set of differential equations are

$$X_1'[t]=-H_1X_1[t]+b_1X_5[t]+b_2X_6[t]+b_3X_7[t]+b_6X_8[t]+b_9X_9[t]+b_4X_4[t]+b_7X_2[t] \quad (1)$$

$$X_2'[t]=-H_2X_2[t]+b_1X_{21}[t]+b_2X_{20}[t]+b_3X_{19}[t]+b_4X_3[t]+b_6X_{18}[t]+b_8X_{17}[t]+b_9X_{16}[t]+a_7X_1[t] \quad (2)$$

$$X_3'[t]=-H_3X_3[t]+b_1X_{28}[t]+b_2X_{27}[t]+b_3X_{26}[t]+b_5X_{25}[t]+b_6X_{24}[t]+b_8X_{23}[t]+b_9X_{22}[t]+a_4X_2[t]+a_7P_4[t] \quad (3)$$

$$X_4'[t]=-H_4X_4[t]+b_1X_{15}[t]+b_2X_{14}[t]+b_3X_{13}[t]+b_5X_{12}[t]+b_6X_{11}[t]+b_9X_{10}[t]+b_7X_3[t]+a_4X_1[t] \quad (4)$$

Where, $H_1=(a_1+a_2+a_3+a_4+a_6+a_7+a_9)$
$H_2=(a_1+a_2+a_3+a_4+b_7+a_6+a_8+a_9)$
$H_3=(a_1+a_2+a_3+a_5+a_6+a_8+a_9+b_7+b_4)$
$H_4=(a_1+a_2+a_3+a_5+a_6+a_7+a_9+b_4)$

Similarly, we get
$X_i'[t]=a_kX_1-b_kX_i$;i=5,6,7,8,9; k=1,2,3,6,9 (5)

$X_i'[t]=a_kX_2-b_kX_i$; i=16,17,18,19,20,21; k=9,8,6,3,2,1 (6)
$X_i'[t]=a_kX_3-b_kX_i$; i=22,23,24,25,26,27,28; k=9,8,6,5,3,2,1 (7)

$X_i'[t]=a_kX_4-b_kX_i$; i=10,11,12,13,14,15; K=9,6,5,3,2,1 (8)

Let the initial condition be $X_k[0]=\begin{cases}1 \text{ for } k=1\\ 0 \text{ for } k\neq 1\end{cases}$

The system of differential equations along with initial condition are solved by using CAS Mathematica.

The Reliability R(t) of the system can be computed by exploitation of equation

$$R(t)=X_1(t)+X_2(t)+X_3(t)+X_4(t) \quad (9)$$

Values of X_1, X_2, X_3, X_4…… given by CAS Mathematica at point 't':

$X_1[t]$ = 0.760513 $\exp^{-12.6861t}$ {0.000134905 $\exp^{11.5467t}$ + 0.00277371 $\exp^{11.6151t}$ + 0.000311515 $\exp^{11.6851t}$ + 0.0121579 $\exp^{11.6868t}$ + 7.54498 * 10^{-30} $\exp^{11.6961t}$ + 4.60889 * 10^{-6} $\exp^{11.7332t}$ + 2.57359 * 10^{-6} $\exp^{11.7613t}$ + 0.002396 $\exp^{11.7987t}$ + 0.001364 $\exp^{11.814633t}$ + 0.000748 $\exp^{12.1614t}$ + 0.009130 $\exp^{12.1622t}$ + 0.000003 $\exp^{12.1699t}$ + 0.000070 $\exp^{12.1707t}$ + 0.048091 $\exp^{12.5659t}$ + 0.001517 $\exp^{12.5975t}$ + 0.000037 $\exp^{12.5975t}$ + 0.131523 $\exp^{12.6059t}$ + 1.522158 * 10^{-7} $\exp^{12.6135t}$ + 0.0000038 $\exp^{12.6135t}$ + 0.005572 $\exp^{12.6199t}$ + 0.092754 $\exp^{12.6325t}$ + 1.217711 * 10^{-7} $\exp^{12.6384t}$ + 0.000003 $\exp^{12.6385t}$ + 0.006305 $\exp^{12.6446t}$ + 1. $\exp^{12.6861t}$}

$X_2[t]$ = 0.037199 $\exp^{-12.6861t}$ {-0.00347739 $\exp^{11.5467t}$ + 0.002044 $\exp^{11.6151t}$ - 0.010358 $\exp^{11.6851t}$ + 0.00741840 $\exp^{11.6868t}$ - 1.563856 * 10^{-28} $\exp^{11.6961t}$ - 0.000234 $\exp^{11.7332t}$ - 0.000586 $\exp^{11.7613t}$ - 0.004324 $\exp^{11.7987t}$ + 0.005965 $\exp^{11.814633t}$ - 0.014279 $\exp^{12.1614t}$ + 0.009770 $\exp^{12.1622t}$ - 0.000051 $\exp^{12.1699t}$ + 0.000074 $\exp^{12.1707t}$ - 0.975855 $\exp^{12.5659t}$ + 0.001525 $\exp^{12.5975t}$ - 0.0007489 $\exp^{12.5975t}$ + 0.132151 $\exp^{12.6059t}$ - 0.000003 $\exp^{12.6135t}$ + 0.0000038 $\exp^{12.6135t}$ - 0.113471 $\exp^{12.6199t}$ + 0.093040 $\exp^{12.6325t}$ - 0.0000025 $\exp^{12.6384t}$ + 0.000003 $\exp^{12.6385t}$ - 0.128604 $\exp^{12.6446t}$ + 1. $\exp^{12.6861t}$}

$X_3[t]$ = 0.000194 $\exp^{-12.6861t}$ {0.669862 $\exp^{11.5467t}$ + 0.393716 $\exp^{11.6151t}$ - 0.0103052 $\exp^{11.6851t}$ + 0.007381 $\exp^{11.6868t}$ + 4.368248 * 10^{-26} $\exp^{11.6961t}$ + 0.045053 $\exp^{11.7332t}$ - 0.000583 $\exp^{11.7613t}$ + 0.8330105 $\exp^{11.7987t}$ - 1.149232 $\exp^{11.814633t}$ - 0.014200 $\exp^{12.1614t}$ + 0.009716 $\exp^{12.1622t}$ + 0.009793 $\exp^{12.1699t}$ - 0.014356 $\exp^{12.1707t}$ - 0.958674 $\exp^{12.5659t}$ - 0.011834 $\exp^{12.5975t}$ - 0.00919278 $\exp^{12.5975t}$ + 0.137977 $\exp^{12.6059t}$ + 0.000581 $\exp^{12.6135t}$ - 0.000719 $\exp^{12.6135t}$ - 0.115021 $\exp^{12.6199t}$ + 0.093698 $\exp^{12.6325t}$ + 0.000473 $\exp^{12.6384t}$ - 0.000583 $\exp^{12.6385t}$ - 0.129128 $\exp^{12.6446t}$ + 1. $\exp^{12.6861t}$}

$X_4[t]$ = 0.003968 $\exp^{-12.6861t}$ {(−0.025999 $\exp^{11.5467t}$ - 0.534323 $\exp^{11.6151t}$ + 0.000310 $\exp^{11.6851t}$ + 0.012096 $\exp^{11.6868t}$ - 1.684443 * 10^{-27} $\exp^{11.6961t}$ - 0.000888 $\exp^{11.7332t}$ + 0.000002 $\exp^{11.7613t}$ - 0.461628 $\exp^{11.7987t}$ - 0.262730 $\exp^{11.814633t}$ + 0.000743 $\exp^{12.1614t}$ +0.009079 $\exp^{12.1622t}$ - 0.000511 $\exp^{12.1699t}$ - 0.013450 $\exp^{12.1707t}$ + 0.047245 $\exp^{12.5659t}$ - 0.011771 $\exp^{12.5975t}$ + 0.000452 $\exp^{12.5975t}$ + 0.137322 $\exp^{12.6059t}$ - 0.000028 $\exp^{12.6135t}$ - 0.000715 $\exp^{12.6135t}$ + 0.005648 $\exp^{12.6199t}$ + 0.093410 $\exp^{12.6325t}$ - 0.0000232 $\exp^{12.6384t}$ - 0.000582 $\exp^{12.6385t}$ + 0.006331 $\exp^{12.6446t}$ + 1. $\exp^{12.6861t}$}

$X_5[t]$ = 0.005557 $\exp^{-12.6861t}$ {-0.000113 $\exp^{11.5467t}$ - 0.002617 $\exp^{11.6151t}$ - 0.000337 $\exp^{11.6851t}$ - 0.013192 $\exp^{11.6868t}$ - 1.278686×10^{-29} $\exp^{11.6961t}$ - 0.000005 $\exp^{11.7332t}$ - 0.000003 $\exp^{11.7613t}$ - 0.003392 $\exp^{11.7987t}$ - 0.002018 $\exp^{11.814633t}$ - 0.083789 $\exp^{12.1614t}$ - 1.239227 $\exp^{12.1622t}$ + 0.000358 $\exp^{12.1699t}$ + 0.007768 $\exp^{12.1707t}$ + 0.062547 $\exp^{12.5659t}$ + 0.001829 $\exp^{12.5975t}$ +

$0.000044 \exp^{12.5975t} + 0.155498 \exp^{12.6059t} + 1.769020 \times 10^{-7} \exp^{12.6135t} + 0.000004 \exp^{12.6135t} + 0.006384 \exp^{12.6199t} + 0.103405 \exp^{12.6325t} + 1.340514 \times 10^{-7} \exp^{12.6384t} + 0.000003 \exp^{12.6385t} + 0.006852 \exp^{12.6446t} + 1. \exp^{12.6861t}\}$

$X_6[t] = 0.059382 \exp^{-12.6861t} \{-0.000009 \exp^{11.5467t} - 0.000203 \exp^{11.6151t} - 0.0000245 \exp^{11.6851t} - 0.000958 \exp^{11.6868t} - 7.274048 * 10^{-31} \exp^{11.6961t} - 3.823715 \exp^{11.7332t} - 2.205762 \exp^{11.7613t} - 0.000215 \exp^{11.7987t} - 0.000125 \exp^{11.814633t} - 0.000121 \exp^{12.1614t} - 0.001478 \exp^{12.1622t} - 4.370824 \times 10^{-7}\ 0.000051 \exp^{12.1699t} - 0.000011 \exp^{12.1707t} - 0.074407 \exp^{12.5659t} - 0.007092 \exp^{12.5975t} - 0.000173 \exp^{12.5975t} - 1.338388 \exp^{12.6059t} + 0.000025 \exp^{12.6135t} + 0.000575 \exp^{12.6135t} + 0.059608 \exp^{12.6199t} + 0.348380 \exp^{12.6325t} + 3.504773 \times 10^{-7} \exp^{12.6384t} + 0.0000088 \exp^{12.6385t} + 0.014608 \exp^{12.6446t} + 1. \exp^{12.6861t}\}$

$X_7[t] = 0.115661 \exp^{-12.6861t} \{-0.000006 \exp^{11.5467t} - 0.000130 \exp^{11.6151t} - 0.0000157 \exp^{11.6851t} - 0.000613 \exp^{11.6868t} - 1.112013 * 10^{-31} \exp^{11.6961t} - 2.444762 \times 10^{-7} \exp^{11.7332t} - 1.409007 \times 10^{-7} \exp^{11.7613t} - 0.000137 \exp^{11.7987t} - 0.000079 \exp^{11.814633t} - 0.000075 \exp^{12.1614t} - 0.000921 \exp^{12.1622t} - 2.720491 \times 10^{-7} \exp^{12.1699t} - 0.000007 \exp^{12.1707t} - 0.03198 \exp^{12.5659t} - 0.001793 \exp^{12.5975t} - 0.000043 \exp^{12.5975t} - 0.196220 \exp^{12.6059t} - 2.974361 \times 10^{-7} 0.000003 \exp^{12.6135t} - 0.000007 \exp^{12.6135t} - 0.014713 \exp^{12.6199t} - 0.800140 \exp^{12.6325t} + 0.000016 \exp^{12.6384t} + 0.000363 \exp^{12.6385t} + 0.046505 \exp^{12.6446t} + 1. \exp^{12.6861t}\}$

$X_8[t] = 0.003464 \exp^{-12.6861t} \{-0.000894 \exp^{11.5467t} - 0.033890 \exp^{11.6151t} - 0.028183 \exp^{11.6851t} - 1.302992 \exp^{11.6868t} + 4.737985 \times 10^{-15} 1.563856 * 10^{-28} \exp^{11.6961t} + 0.000123 \exp^{11.7332t} + 0.000039 \exp^{11.7613t} + 0.023104 \exp^{11.7987t} + 0.011388 \exp^{11.814633t} + 0.001590 \exp^{12.1614t} + 0.0193887 \exp^{12.1622t} + 0.0000055 \exp^{12.1699t} + 0.000145 \exp^{12.1707t} + 0.0547361 \exp^{12.5659t} + 0.001666 \exp^{12.5975t} + 0.000040 \exp^{12.5975t} + 0.143113 \exp^{12.6059t} + 1.642553 \times 10^{-7} \exp^{12.6135t} + 0.000004 \exp^{12.6135t} + 0.005971 \exp^{12.6199t} + 0.098059 \exp^{12.6325t} + 1.279267 \times 10^{-7} 0.0000025 \exp^{12.6384t} + 0.000003 \exp^{12.6385t} + 0.006581 \exp^{12.6446t} + 1. \exp^{12.6861t}\}$

$X_9[t] = 0.003464 \exp^{-12.6861t} \{-0.000894 \exp^{11.5467t} - 0.033890 \exp^{11.6151t} - 0.0281831 \exp^{11.6851t} - 1.30299 \exp^{11.6868t} - 4.737985 * 10^{-15} \exp^{11.6961t} + 0.000123 \exp^{11.7332t} + 0.000039 \exp^{11.7613t} + 0.0231043 \exp^{11.7987t} + 0.011388 \exp^{11.814633t} + 0.001590 \exp^{12.1614t} + 0.0193887 \exp^{12.1622t} + 0.0000055 \exp^{12.1699t} + 0.000145 \exp^{12.1707t} + 0.0547361 \exp^{12.5659t} + 0.001666 \exp^{12.5975t} + 0.000040 \exp^{12.5975t} + 0.143113 \exp^{12.6059t} + 1.642554 \times 10^{-7} \exp^{12.6135t} + 0.000004 \exp^{12.6135t} + 0.0059708 \exp^{12.6199t} + 0.0980593 \exp^{12.6325t} + 1.279267 \times 10^{-7} \exp^{12.6384t} + 0.000003 \exp^{12.6385t} + 0.006581 \exp^{12.6446t} + 1. \exp^{12.6861t}\}$

$X_{10}[t] = 0.00001807 \exp^{-12.6861t} \{0.172181 \exp^{11.5467t} + 6.528583 \exp^{11.6151t} - 0.028040 \exp^{11.6851t} - 1.296375 \exp^{11.6868t} - 1.110241 * 10^{-11} \exp^{11.6961t} - 0.023693 \exp^{11.7332t} + 0.000039 \exp^{11.7613t} - 4.4512045 \exp^{11.7987t} - 2.193971 \exp^{11.814633t} + 0.0015816 \exp^{12.1614t} + 0.019281 \exp^{12.1622t} - 0.001068 \exp^{12.1699t} - 0.028051 \exp^{12.1707t} + 0.053772 \exp^{12.5659t} - 0.0129282 \exp^{12.5975t} + 0.000496 \exp^{12.5975t} + 0.1494227 \exp^{12.6059t} - 0.0000308 \exp^{12.6135t} - 0.000772 \exp^{12.6135t} + 0.006052 \exp^{12.6199t} + 0.09875337 \exp^{12.6325t} - 0.00002439 \exp^{12.6384t} - 0.000612 \exp^{12.6385t} + 0.006608 \exp^{12.6446t} + 1. \exp^{12.6861t}\}$

$X_{11}[t] = 0.00001807 \exp^{-12.6861t} \{0.172181 \exp^{11.5467t} + 6.528583 \exp^{11.6151t} - 0.028040 \exp^{11.6851t} - 1.296375 \exp^{11.6868t} - 1.110241 * 10^{-11} \exp^{11.6961t} - 0.023693 \exp^{11.7332t} + 0.000039 \exp^{11.7613t} - 4.4512045 \exp^{11.7987t} - 2.193971 \exp^{11.814633t} + 0.0015816 \exp^{12.1614t} + 0.019281 \exp^{12.1622t} - 0.001068 \exp^{12.1699t} - 0.028051 \exp^{12.1707t} + 0.053772 \exp^{12.5659t} - 0.0129282 \exp^{12.5975t} + 0.000496 \exp^{12.5975t} + 0.1494227 \exp^{12.6059t} - 0.0000308 \exp^{12.6135t} - 0.000772 \exp^{12..6135t} + 0.006052 \exp^{12.6199t} + 0.09875337 \exp^{12.6325t} - 0.00002439 \exp^{12.6384t} - 0.000612 \exp^{12.6385t} + 0.006608 \exp^{12.6446t} + 1. \exp^{12.6861t}\}$

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$$X_{12}[t] = 0.0001917\ \mathrm{exp}^{-12.6861t}\ \{0.0022018\ \mathrm{exp}^{11.5467t} + 0.048425\ \mathrm{exp}^{11.6151t} - 0.00003\ \mathrm{exp}^{11.6851t} - 0.0011827\ \mathrm{exp}^{11.6868t} + 1.070318 * 10^{-27}\ \mathrm{exp}^{11.6961t} + 0.000091\ \mathrm{exp}^{11.7332t} - 2.726673 \times 10^{-7}\ \mathrm{exp}^{11.7613t} + 0.0514637\ \mathrm{exp}^{11.7987t} + 0.029884\ \mathrm{exp}^{11.814633t} - 0.0001519\ \mathrm{exp}^{12.1614t} - 0.0018582\ \mathrm{exp}^{12.1622t} + 0.0001065\ \mathrm{exp}^{12.1699t} + 0.0028077\ \mathrm{exp}^{12.1707t} - 0.13484605\ \mathrm{exp}^{12.5659t} - 2.7397497\ \mathrm{exp}^{12.5975t} + 0.094978\ \mathrm{exp}^{12.5975t} + 1.384688\ \mathrm{exp}^{12.6059t} - 0.0001547\ \mathrm{exp}^{12.6135t} - 0.0038635\ \mathrm{exp}^{12.6135t} + 0.0220237\ \mathrm{exp}^{12.6199t} + 0.234608\ \mathrm{exp}^{12.6325t} - 0.00004995\ \mathrm{exp}^{12.6384t} - 0.00125177\ \mathrm{exp}^{12.6385t} + 0.0118601964\ \mathrm{exp}^{12.6446t} + 1.\ \mathrm{exp}^{12.6861t}\}$$

$$X_{13}[t] = 0.00060345\ \mathrm{exp}^{-12.6861t}\ \{0.0011428998\ \mathrm{exp}^{11.5467t} + 0.0250703\ \mathrm{exp}^{11.6151t} - 0.0000156\ \mathrm{exp}^{11.6851t} - 0.0006104\ \mathrm{exp}^{11.6868t} - 2.647499 \times 10^{-29}\ \mathrm{exp}^{11.6961t} + 0.000047\ \mathrm{exp}^{11.7332t} - 1.401795 \times 10^{-7}\ \mathrm{exp}^{11.7613t} + 0.0263999\ \mathrm{exp}^{11.7987t} + 0.01531494\ \mathrm{exp}^{11.814633t} - 0.0000749\ \mathrm{exp}^{12.1614t} - 0.0009158\ \mathrm{exp}^{12.1622t} + 0.000052\ \mathrm{exp}^{12.1699t} + 0.0013814\ \mathrm{exp}^{12.1707t} - 0.031417\ \mathrm{exp}^{12.5659t} + 0.01391038\ \mathrm{exp}^{12.5975t} - 0.0005347\ \mathrm{exp}^{12.5975t} - 0.2048708\ \mathrm{exp}^{12.6059t} + 0.0000558\ \mathrm{exp}^{12.6135t} + 0.0014010\ \mathrm{exp}^{12.6135t} - 0.0149146\ \mathrm{exp}^{12.6199t} - 0.8058036\ \mathrm{exp}^{12.6325t} - 0.003066\ \mathrm{exp}^{12.6384t} - 0.0692467\ \mathrm{exp}^{12.6385t} + 0.0466945\ \mathrm{exp}^{12.6446t} + 1.\ \mathrm{exp}^{12.6861t}\}$$

$$X_{14}[t] = 0.0003098\ \mathrm{exp}^{-12.6861t}\ \{0.0017789\ \mathrm{exp}^{11.5467t} + 0.0390828\ \mathrm{exp}^{11.6151t} - 0.0000244\ \mathrm{exp}^{11.6851t} - 0.0009533\ \mathrm{exp}^{11.6868t} + 3.5175296 * 10^{-28}\ \mathrm{exp}^{11.6961t} + 0.0000736637\ \mathrm{exp}^{11.7332t} - 2.1944719 \times 10^{-7}\ \mathrm{exp}^{11.7613t} + 0.0413824\ \mathrm{exp}^{11.7987t} + 0.02402075\ \mathrm{exp}^{11.814633t} - 0.00012017\ \mathrm{exp}^{12.1614t} - 0.0014700756\ \mathrm{exp}^{12.1622t} + 0.00008424\ \mathrm{exp}^{12.1699t} + 0.00221967\ \mathrm{exp}^{12.1707t} - 0.0730969\ \mathrm{exp}^{12.5659t} + 0.05501996\ \mathrm{exp}^{12.5975t} - 0.0021185\ \mathrm{exp}^{12.5975t} - 1.397394\ \mathrm{exp}^{12.6059t} - 0.00478968\ \mathrm{exp}^{12.6135t} - 0.107891\ \mathrm{exp}^{12.6135t} + 0.0604226\ \mathrm{exp}^{12.6199t} + 0.3508458\ \mathrm{exp}^{12.6325t} - 0.0000668\ \mathrm{exp}^{12.6384t} - 0.0016734\ \mathrm{exp}^{12.6385t} + 0.014668\ \mathrm{exp}^{12.6446t} + 1.\ \mathrm{exp}^{12.6861t}\}$$

$$X_{15}[t] = 0.000028996\ \mathrm{exp}^{-12.6861t}\ \{0.021816097\ \mathrm{exp}^{11.5467t} + 0.504238\ \mathrm{exp}^{11.6151t} - 0.000335\ \mathrm{exp}^{11.6851t} - 0.013124989\ \mathrm{exp}^{11.6868t} + 5.085316 * 10^{-27}\ \mathrm{exp}^{11.6961t} + 0.0010665\ \mathrm{exp}^{11.7332t} - 0.0000032896\ \mathrm{exp}^{11.7613t} + 0.65349385\ \mathrm{exp}^{11.7987t} + +0.3887349\ \mathrm{exp}^{11.814633t} - 0.08332268\ \mathrm{exp}^{12.1614t} - 1.2323247\ \mathrm{exp}^{12.1622t} - 0.06906097\ \mathrm{exp}^{12.1699t} - 1.49729091\ \mathrm{exp}^{12.1707t} + 0.061445998\ \mathrm{exp}^{12.5659t} - 0.014189049\ \mathrm{exp}^{12.5975t} + 0.00054485\ \mathrm{exp}^{12.5975t} + 0.162353698\ \mathrm{exp}^{12.6059t} - 0.00003321\ \mathrm{exp}^{12.6135t} - 0.00083154\ \mathrm{exp}^{12.6135t} + 0.0064714\ \mathrm{exp}^{12.6199t} + 0.10413727899\ \mathrm{xp}^{12.6325t} - 0.0000255556\ \mathrm{exp}^{12.6384t} - 0.0006410095\ \mathrm{exp}^{12.6385t} + 0.006879901298\ \mathrm{exp}^{12.6446t} + 1.\ \mathrm{exp}^{12.6861t}\}$$

$$X_{16}[t] = 0.0001695\ \mathrm{exp}^{-12.6861t}\ \{0.0230399\ \mathrm{exp}^{11.5467t} - 0.024972043\ \mathrm{exp}^{11.6151t} + 0.9370836007\ \mathrm{exp}^{11.6851t} - 0.79505008079\ \mathrm{exp}^{11.6868t} + 4.632050786089 * 10^{-13}\ \mathrm{exp}^{11.6961t} - 0.00624058431\ \mathrm{exp}^{11.7332t} - 0.008895899\ \mathrm{exp}^{11.7613t} - 0.04169174558\ \mathrm{exp}^{11.7987t} + 0.049812587\ \mathrm{exp}^{11.814633t} - 0.0303775236\ \mathrm{exp}^{12.1614t} + 0.02074887\ \mathrm{exp}^{12.1622t} - 0.00010615157\ \mathrm{exp}^{12.1699t} + 0.000155346\ \mathrm{exp}^{12.1707t} - 1.110688657\ \mathrm{exp}^{12.5659t} + 0.0016752789\ \mathrm{exp}^{12.5975t} - 0.00082251004\ \mathrm{exp}^{12.5975t} + 0.143795962196\ \mathrm{exp}^{12.6059t} - 0.0000033438\ \mathrm{exp}^{12.6135t} + 0.00000413024\ \mathrm{exp}^{12.6135t} - 0.1215996941\ \mathrm{exp}^{12.6199t} + 0.098361744218\ \mathrm{exp}^{12.6325t} - 0.000002608\ \mathrm{exp}^{12.6384t} + 0.0000032176\ \mathrm{exp}^{12.6385t} - 0.13422982\ \mathrm{exp}^{12.6446t} + 1.\ \mathrm{exp}^{12.6861t}\}$$

$$X_{17}[t] = 0.0001940818\ \mathrm{exp}^{-12.6861t}\ \{0.0145802809\ \mathrm{exp}^{11.5467t} - 0.0124502338\ \mathrm{exp}^{11.6151t} + 0.1177276\ \mathrm{exp}^{11.6851t} - 0.08613262349\ \mathrm{exp}^{11.6868t} + 1.4486338076 * 10^{-28}\ \mathrm{exp}^{11.6961t} + 0.0065394829\ \mathrm{exp}^{11.7332t} + 0.11396126\ \mathrm{exp}^{11.7613t} - 0.1217538389\ \mathrm{exp}^{11.7987t} + 0.11302803\ \mathrm{exp}^{11.814633t} - 0.0332277\ \mathrm{exp}^{12.1614t} + 0.0226887\ \mathrm{exp}^{12.1622t} - 0.0001157\ \mathrm{exp}^{12.1699t} + 0.0001693\ \mathrm{exp}^{12.1707t} - 1.122489\ \mathrm{exp}^{12.5659t} + 0.0016879\ \mathrm{exp}^{12.5975t} - 0.0008287\ \mathrm{exp}^{12.5975t} + 0.144766\ \mathrm{exp}^{12.6059t} - 0.00000336\ \mathrm{exp}^{12.6135t} + 0.00000415\ \mathrm{exp}^{12.6135t} - 0.122266\ \mathrm{exp}^{12.6199t} + 0.0987917\ \mathrm{exp}^{12.6325t} - 0.000002618\ \mathrm{exp}^{12.6384t} + 0.00000323\ \mathrm{exp}^{12.6385t} - 0.13467808\ \mathrm{exp}^{12.6446t} + 1.\ \mathrm{exp}^{12.6861t}\}$$

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$$X_{18}[t] = 0.00016946\,\exp^{-12.6861t}\{0.0230399226\exp^{11.5467t} - 0.024972043\exp^{11.6151t} + 0.9370836\exp^{11.6851t} - 0.79505008\exp^{11.6868t} - 4.632050786 * 10^{-13}\exp^{11.6961t} - 0.00624058\exp^{11.7332t} - 0.008895899\exp^{11.7613t} - 0.0416917\exp^{11.7987t} + 0.049812587\exp^{11.814633t} - 0.030377\exp^{12.1614t} + 0.02074887\exp^{12.1622t} - 0.00010615\exp^{12.1699t} + 0.000155346\exp^{12.1707t} - 1.110688657\exp^{12.5659t} + 0.0016752789\exp^{12.5975t} - 0.0008225\exp^{12.5975t} 0.14379596\exp^{12.6059t} - 0.0000033438\exp^{12.6135t} + 0.00000413\exp^{12.6135t} - 0.12159969\exp^{12.6199t} + 0.0983617\exp^{12.6325t} - 0.000002608\exp^{12.6384t} + 0.0000032176\exp^{12.6385t} - 0.1342298\exp^{12.6446t} + 1.\exp^{12.6861t}\}$$

$$X_{19}[t] = 0.005657\,\exp^{-12.6861t}\{0.0001529\exp^{11.5467t} - 0.00009589\exp^{11.6151t} + 0.000521726\exp^{11.6851t} - 0.0003743368\exp^{11.6868t} - 4.775531597 * 10^{-29}\exp^{11.6961t} + 0.000012405\exp^{11.7332t} + 0.00003210789\exp^{11.7613t} + 0.00024727176\exp^{11.7987t} - 0.000347715\exp^{11.814633t} + 0.00143799\exp^{12.1614t} - 0.0009855786\exp^{12.1622t} + 0.000005209\exp^{12.1699t} - 0.00000765\exp^{12.1707t} + 0.64892975\exp^{12.5659t} - 0.00180255\exp^{12.5975t} + 0.0008859\exp^{12.5975t} - 0.1971560188\exp^{12.6059t} + 0.000006055\exp^{12.6135t} - 0.000007494338\exp^{12.6135t} + 0.299651684\exp^{12.6199t} - 0.8026080703456\exp^{12.6325t} - 0.0003279458\exp^{12.6384t} + 0.000364217\exp^{12.6385t} - 0.9485340353\exp^{12.6446t} + 1.\exp^{12.6861t}\}$$

$$X_{20}[t] = 0.037199\,\exp^{-12.6861t}\{-0.00347739\exp^{11.5467t} + 0.002044\exp^{11.6151t} - 0.010358\exp^{11.6851t} + 0.00741840\exp^{11.6868t} - 1.563856 * 10^{-28}\exp^{11.6961t} - 0.000234\exp^{11.7332t} - 0.000586\exp^{11.7613t} - 0.004324\exp^{11.7987t} + 0.005965\exp^{11.814633t} - 0.014279\exp^{12.1614t} + 0.009770\exp^{12.1622t} - 0.000051\exp^{12.1699t} + 0.000074\exp^{12.1707t} - 0.975855\exp^{12.5659t} + 0.001525\exp^{12.5975t} - 0.0007489\exp^{12.5975t} + 0.132151\exp^{12.6059t} - 0.000003\exp^{12.6135t} + 0.0000038\exp^{12.6135t} - 0.113471\exp^{12.6199t} + 0.34945446\exp^{12.6325t} - 0.0000071458\exp^{12.6384t} + 0.0000088016\exp^{12.6385t} - 0.2979598\exp^{12.6446t} + 1.\exp^{12.6861t}\}$$

$$X_{21}[t] = 0.0002718\,\exp^{-12.6861t}\{0.00291925\exp^{11.5467t} - 0.001928728\exp^{11.6151t} + 0.01119897\exp^{11.6851t} - 0.008049387\exp^{11.6868t} - 1.1022617398 * 10^{-27}\exp^{11.6961t} + 0.00028091398\exp^{11.7332t} + 0.00075348\exp^{11.7613t} + 0.00612088\exp^{11.7987t} - 0.0088259578\exp^{11.814633t} + 1.600325438\exp^{12.1614t} - 1.326164349499\exp^{12.1622t} - 0.0068611206\exp^{12.1699t} + 0.008291875\exp^{12.1707t} - 1.2691897\exp^{12.5659t} + 0.00183866\exp^{12.5975t} - 0.00090268\exp^{12.5975t} + 0.15623996686\exp^{12.6059t} - 0.0000036\exp^{12.6135t} + 0.00000444799\exp^{12.6135t} - 0.1300177\exp^{12.6199t} + 0.1037243033\exp^{12.6325t} - 0.0000027\exp^{12.6384t} + 0.00000337\exp^{12.6385t} - 0.1397555259\exp^{12.6446t} + 1.\exp^{12.6861t}\}$$

$$X_{22}[t] = 8.841505 \times 10^{-7}\exp^{-12.6861t}\{-4.43825826\exp^{11.5467t} + 4.81058049678\exp^{11.6151t} + 0.93232541628\exp^{11.6851t} - 0.79101242406\exp^{11.6868t} - 1.0610265775 * 10^{-10}\exp^{11.6961t} + 1.2022466\exp^{11.7332t} - 0.00885\exp^{11.7613t} + 8.032216157\exp^{11.7987t} - 9.596855\exp^{11.814633t} - 0.030208365\exp^{12.1614t} + 0.02063329\exp^{12.1622t} + 0.02046\exp^{12.1699t} - 0.029942068\exp^{12.1707t} - 1.091132965\exp^{12.5659t} - 0.012997\exp^{12.5975t} - 0.010096\exp^{12.5975t} + 0.150135\exp^{12.6059t} + 0.0006277\exp^{12.6135t} - 0.0007754388\exp^{12.6135t} - 0.1232613414166\exp^{12.6199t} + 0.0990579\exp^{12.6325t} + 0.0004972448\exp^{12.6384t} - 0.0006134\exp^{12.6385t} - 0.1347771\exp^{12.6446t} + 1.\exp^{12.6861t}\}$$

$$X_{23}[t] = 0.0000010126\,\exp^{-12.6861t}\{-2.8086488\exp^{11.5467t} + 2.398396\exp^{11.6151t} + 0.1171298\exp^{11.6851t} - 0.085695\exp^{11.6868t} - 3.01091279 * 10^{-25}\exp^{11.6961t} - 1.259829\exp^{11.7332t} + 0.1133779\exp^{11.7613t} + 23.456757\exp^{11.7987t} - 21.77589\exp^{11.814633t} - 0.0330427\exp^{12.1614t} + 0.02256234\exp^{12.1622t} + 0.02230897\exp^{12.1699t} - 0.032638\exp^{12.1707t} - 1.1027257\exp^{12.5659t} - 0.013095\exp^{12.5975t} - 0.0101721\exp^{12.5975t} + 0.1511489\exp^{12.6059t} + 0.0006315\exp^{12.6135t} - 0.00078\exp^{12.6135t} - 0.1239368\exp^{12.6199t} + 0.09949\exp^{12.6325t} + 0.000499\exp^{12.6384t} - 0.0006157788\exp^{12.6385t} - 0.135227\exp^{12.6446t} + 1.\exp^{12.6861t}\}$$

$$X_{24}[t] = 8.841505\times10^{-7}\exp^{-12.6861t}\{-4.43825826\exp^{11.5467t}+4.81058049678\exp^{11.6151t}+0.93232541628\exp^{11.6851t}-0.79101242406\exp^{11.6868t}-1.0610265775*10^{-10}\exp^{11.6961t}+1.2022466\exp^{11.7332t}-0.00885\exp^{11.7613t}+8.032216157\exp^{11.7987t}-9.596855\exp^{11.814633t}-0.030208365\exp^{12.1614t}+0.02063329\exp^{12.1622t}+0.02046\exp^{12.1699t}-0.029942068\exp^{12.1707t}-1.091132965\exp^{12.5659t}-0.012997\exp^{12.5975t}-0.010096\exp^{12.5975t}+0.150135\exp^{12.6059t}+0.0006277\exp^{12.6135t}-0.0007754388\exp^{12.6135t}-0.1232613414166\exp^{12.6199t}+0.0990579\exp^{12.6325t}+0.0004972448\exp^{12.6384t}-0.0006134\exp^{12.6385t}-0.1347771\exp^{12.6446t}+1.\exp^{12.6861t}\}$$

$$X_{25}[t] = 0.0000093769869\exp^{-12.6861t}\{-0.05675608\exp^{11.5467t}+0.0356820657\exp^{11.6151t}+0.0010057\exp^{11.6851t}-0.00072166\exp^{11.6868t}-6.2146051697*10^{-27}\exp^{11.6961t}-0.004641439\exp^{11.7332t}+0.000062134339\exp^{11.7613t}-0.0928664698\exp^{11.7987t}+0.13072029\exp^{11.814633t}+0.00290097\exp^{12.1614t}-0.00198859\exp^{12.1622t}-0.00204043599\exp^{12.1699t}+0.0029969839\exp^{12.1707t}+2.7362547\exp^{12.5659t}-2.754349396\exp^{12.5975t}-1.93148422\exp^{12.5975t}+1.39129317\exp^{12.6059t}+0.00315012316\exp^{12.6135t}-0.003880\exp^{12.6135t}-0.44852730\exp^{12.6199t}+0.2353317\exp^{12.6325t}+0.001018420988\exp^{12.6384t}-0.001255179\exp^{12.6385t}-0.2419055\exp^{12.6446t}+1.\exp^{12.6861t}\}$$

$$X_{26}[t] = 0.0000295166\exp^{-12.6861t}\{-0.02946\exp^{11.5467t}+0.018473003877\exp^{11.6151t}+0.000519077\exp^{11.6851t}-0.0003724357\exp^{11.6868t}-4.7871908*10^{-27}\exp^{11.6961t}-0.0023898289\exp^{11.7332t}+0.0000319\exp^{11.7613t}-0.04763869\exp^{11.7987t}+0.06699\exp^{11.814633t}+0.001429987\exp^{12.1614t}-0.0009800886\exp^{12.1622t}-0.001004082797\exp^{12.1699t}+0.0014745\exp^{12.1707t}+0.637504162968\exp^{12.5659t}+0.013984509\exp^{12.5975t}+0.0108746\exp^{12.5975t}-0.2058480639\exp^{12.6059t}-0.001136723789\exp^{12.6135t}+0.00140703699979\exp^{12.6135t}+0.30374639\exp^{12.6199t}-0.808288807\exp^{12.6325t}+0.06251970508\exp^{12.6384t}-0.06943514768\exp^{12.6385t}-0.95240153648\exp^{12.6446t}+1.\exp^{12.6861t}\}$$

$$X_{27}[t] = 0.00001515\exp^{-12.6861t}\{-0.04585428\exp^{11.5467t}+0.028798\exp^{11.6151t}+0.000810698\exp^{11.6851t}-0.0005817\exp^{11.6868t}+2.64043198*10^{-26}\exp^{11.6961t}-0.0037378\exp^{11.7332t}+0.000050\exp^{11.7613t}-0.07467475\exp^{11.7987t}+0.10507\exp^{11.814633t}+0.002295\exp^{12.1614t}-0.00157\exp^{12.1622t}-0.00161319\exp^{12.1699t}+0.002369\exp^{12.1707t}+1.4832594627\exp^{12.5659t}+0.05531315\exp^{12.5975t}+0.0430826\exp^{12.5975t}-1.40405986\exp^{12.6059t}+0.09750545\exp^{12.6135t}-0.10835226637\exp^{12.6135t}-1.2305458\exp^{12.6199t}+0.3519278\exp^{12.6325t}+0.001362288\exp^{12.6384t}-0.001677957\exp^{12.6385t}-0.2991747\exp^{12.6446t}+1.\exp^{12.6861t}\}$$

$$X_{28}[t] = 0.000001418\exp^{-12.6861t}\{-0.5623459\exp^{11.5467t}+0.3715476\exp^{11.6151t}+0.011142111\exp^{11.6851t}-0.0080085\exp^{11.6868t}+0.3715476\exp^{11.6961t}+0.011142\exp^{11.7332t}-0.0080085\exp^{11.7613t}-8.9500687\times10^{-26}\exp^{11.7987t}-0.05411799\exp^{11.814633t}+0.0007496\exp^{12.1614t}-1.17923224\exp^{12.1622t}+1.70040237\exp^{12.1699t}-1.5982085\exp^{12.1707t}-1.246843\exp^{12.5659t}-0.01426466\exp^{12.5975t}-0.011080167\exp^{12.5975t}+0.163128\exp^{12.6059t}+0.00067607\exp^{12.6135t}-0.000835\exp^{12.6135t}-0.13179\exp^{12.6199t}+0.1044584\exp^{12.6325t}+0.00052105\exp^{12.6384t}-0.00064275\exp^{12.6385t}-0.140325357\exp^{12.6446t}+1.\exp^{12.6861t}\}$$

4. The analysis of performance of each of unit of cattle feed plant by exploitation CAS Mathematica

The reliability of the system is calculated by using equation (9) for various values of failure and repair rates and presented by tables:

***(i) Effect of failure rate of Elevator on reliability of the system*:**

In Table-1,The reliability of the system is studied by varying the failure rate of elevator as; a_1=0.0038, 0.0068, 0.0098 and a_2=0.0057,a_3=0.00730,a_4=0.0048,a_5=0.0043,a_6=0.00451,a_7=0.0045,a_8=a_4=0.0048,

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$a_9=a_6=0.00451, b_1=0.52, b_2=0.073, b_3=0.048, b_4=0.92, b_5=0.089, b_6=0.99, b_7=0.092, b_8=b_4=0.92, b_9=b_6=0.99$ are kept fixed. We observed that the reliability of the Elevator is approximately 80%.

Table 1: Effect of Failure rate of Elevator on reliability of the system.

t \ a_1	0.0038	0.0068	0.0098
30	0.8264062	0.8224809	0.8185927
60	0.8057313	0.8020096	0.7983220
90	0.8025521	0.7988553	0.7951925
120	0.8020015	0.7983083	0.7946490
150	0.8018990	0.7982063	0.7945475
180	0.8018791	0.7981865	0.7945278
210	0.8018752	0.7981826	0.7945239
240	0.8018744	0.7981818	0.7945232
270	0.8018742	0.7981817	0.7945230
300	0.8018742	0.7981816	0.7945230
330	0.8018742	0.7981816	0.7945230
360	0.8018742	0.7981816	0.7945230

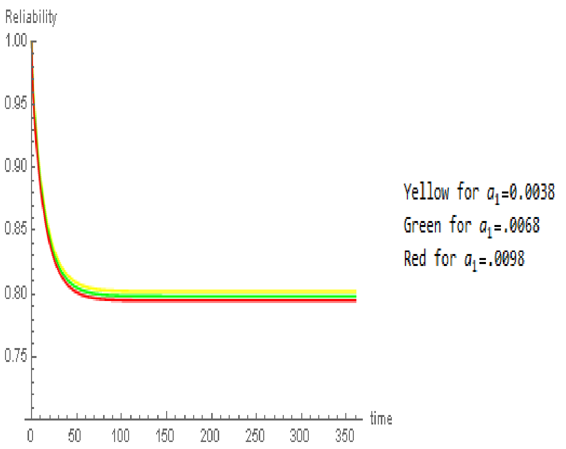

Fig.-1

***(ii) Effect of failure rate of Grinder on reliability of the system*:**

In Table-2, The reliability of the system is studied by varying the failure rate of grinder as; $a_2=0.0057, 0.0077, 0.0097$ and $a_1=0.0038$, $a_3=0.00730$, $a_4=0.0048, a_5=0.0043, a_6=0.00451, a_7=0.0045, a_8=a_4=0.0048, a_9=a_6=0.00451, b_1=0.52, b_2=0.073, b_3=0.048, b_4=0.92, b_5=0.089, b_6=0.99, b_7=0.092, b_8=b_4=0.92, b_9=b_6=0.99$ are kept fixed. We observed that the reliability of the Grinder is approximately 78%.

Table 2: Effect of Failure rate of Grinder on reliability of the system.

t \ a_2	0.0057	0.0077	0.0097
30	0.8264062	0.8089644	0.7921505
60	0.8057313	0.7882365	0.7714810
90	0.8025521	0.7852546	0.7686890
120	0.8020015	0.7847524	0.7682302
150	0.8018990	0.7846591	0.7681451
180	0.8018791	0.7846410	0.7681284
210	0.8018752	0.7846373	0.7681250
240	0.8018744	0.7846366	0.7681243
270	0.8018742	0.7846364	0.7681242
300	0.8018742	0.7846364	0.7681241
330	0.8018742	0.7846364	0.7681241
360	0.8018742	0.7846364	0.7681241

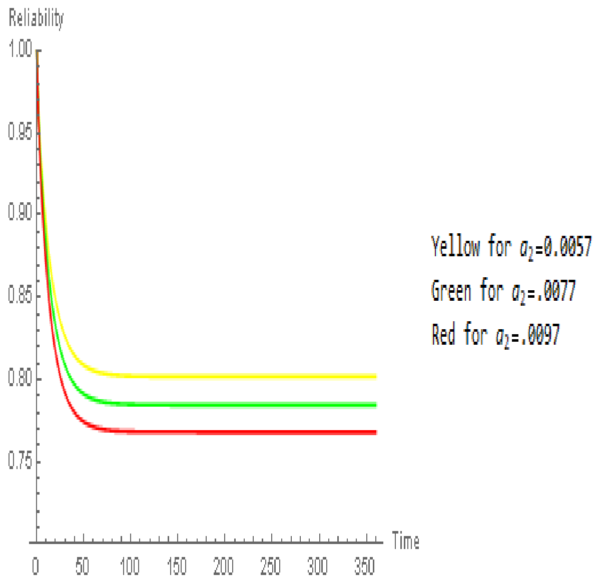

Fig.-2

***(iii)Effect of failure rate of Hopper on reliability of the system*:**

In Table-3, The reliability of the system is studied by varying the failure rate of hopper as; $a_3=0.00730, 0.0083, 0.0093$ and $a_1=0.0038, a_2=0.0057, a_4=0.0048, a_5=0.0043, a_6=0.00451, a_7=0.0045, a_8=a_4=0.0048, a_9=a_6=0.00451, b_1=0.52, b_2=0.073, b_3=0.048, b_4=0.92, b_5=0.089, b_6=0.99, b_7=0.092, b_8=b_4=0.92, b_9=b_6=0.99$ are kept fixed. We observed that the reliability of the Hopper is approximately 79%.

Table 3: Effect of Failure rate of hopper on reliability of the system

t \ a_3	0.0073	0.0083	0.0093
30	0.8264062	0.8147257	0.8032954
60	0.8057313	0.7927260	0.7801043
90	0.8025521	0.7893926	0.7766502
120	0.8020015	0.7888261	0.7760750
150	0.8018990	0.7887227	0.7759721
180	0.8018791	0.7887031	0.7759531
210	0.8018752	0.7886994	0.7759495
240	0.8018744	0.7886986	0.7759488
270	0.8018742	0.7886985	0.7759487
300	0.8018742	0.7886984	0.7759487
330	0.8018742	0.7886984	0.7759487
360	0.8018742	0.7886984	0.7759487

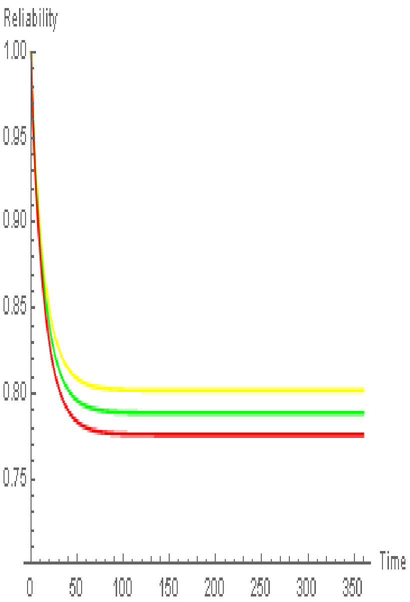

Fig.-3

***(iv) Effect of failure rate of Mixer on reliability of the system*:** In Table-4, The reliability of the system is studied by varying the failure rate of mixer as; $a_4=a_8=0.0048,0.0068,0.0088$ and $a_1=0.0038,a_2=0.0057,a_3=0.0073,a_5=0.0043,a_6=0.00451,a_7=0.0045,,a_9=a_6=0.00451,b_1=0.52,b_2=0.073,b_3=0.048,b_4=0.92,b_5=0.089,b_6=0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99$ are kept fixed. We observed that the reliability of the mixer is approximately 80%.

Table 4: Effect of Failure rate of mixer on reliability of the system.

t \ a_4	0.0048	0.0068	0.0088
30	0.8264062	0.8262715	0.8261372
60	0.8057312	0.8055982	0.8054654
90	0.8025521	0.8024201	0.8022883
120	0.8020015	0.8018697	0.8017381
150	0.8018990	0.8017671	0.8016356
180	0.8018791	0.8017473	0.8016157
210	0.8018752	0.8017433	0.8016118
240	0.8018744	0.8017425	0.8016110
270	0.8018742	0.8017424	0.8016109
300	0.8018742	0.8017424	0.8016108
330	0.8018742	0.8017424	0.8016108
360	0.8018742	0.8017424	0.8016108

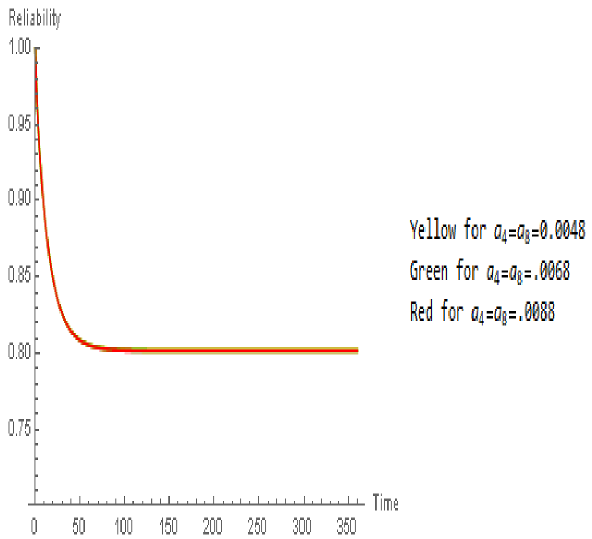

Fig.-4

***(v) Effect of failure rate of Winch on reliability of the system*:**

In Table-5, The reliability of the system is studied by varying the failure rate of winch as; $a_5=0.0043,.0063,.0083$ $a_1=0.0038,a_2=0.0057,a_3=0.0073,a_4=0.0048,a_5=0.0043,a_6=00451,a_7=0.0045,a_8=a_4=0.0048,a_9=a_6=0.00451,b_1=0.52,b_2=0.073,b_3=0.048,b_4=0.92,b_5=0.089,b_6=0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99$ are kept fixed. We observed that the reliability of the winch is approximately 80%.

Table 5: Effect of Failure rate of winch on reliability of the system.

a_5 \ t	0.0043	0.0063	0.0083
30	0.8264062	0.8263283	0.8262505
60	0.8057312	0.8056550	0.8055788
90	0.8025521	0.8024769	0.8024017
120	0.8020015	0.8019265	0.8018515
150	0.8018990	0.8018240	0.8017490
180	0.8018791	0.8018041	0.8017291
210	0.8018752	0.8018002	0.8017252
240	0.8018744	0.8017994	0.8017244
270	0.8018742	0.8017993	0.8017243
300	0.8018742	0.8017992	0.8017242
330	0.8018742	0.8017992	0.8017242
360	0.8018742	0.8017992	0.8017242

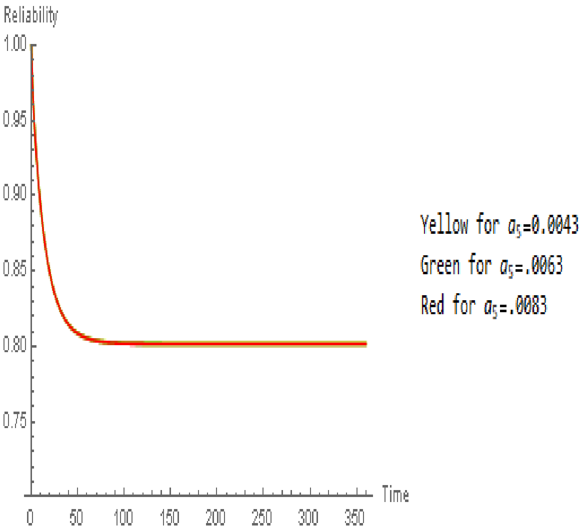

Fig.-5

***(vi) Effect of failure rate of Palletiser on reliability of the system*:**

In Table-6, The reliability of the system is studied by varying the failure rate of palletiser as:$a_6=a_9=0.00451,.00651,.00851,a_1=0.0038,a_2=0.0057,a_3=0.0073,a_4=0.0048,a_5=0.0043,,a_7=0.0045,a_8=a_4=0.0048,b_1=0.52,b_2=0.073,b_3=0.048,b_4=0.92,b_5=0.089,b_6=0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99$ are kept fixed. We observed that the reliability of the palletiser is approximately 80%.

Table 6: Effect of failure rate of palletiser on reliability of the system.

a_6 \ t	0.00451	0.00651	0.00851
30	0.8264062	0.8236647	0.8209414
60	0.8057312	0.8031226	0.8005306
90	0.8025521	0.7999597	0.7973841
120	0.8020015	0.7994115	0.7968382
150	0.8018990	0.7993093	0.7967363
180	0.8018791	0.7992895	0.7967166
210	0.8018752	0.7992856	0.7967127
240	0.8018744	0.7992848	0.7967119
270	0.8018742	0.7992846	0.7967117
300	0.8018742	0.7992846	0.7967117
330	0.8018742	0.7992846	0.7967117
360	0.8018742	0.7992846	0.7967117

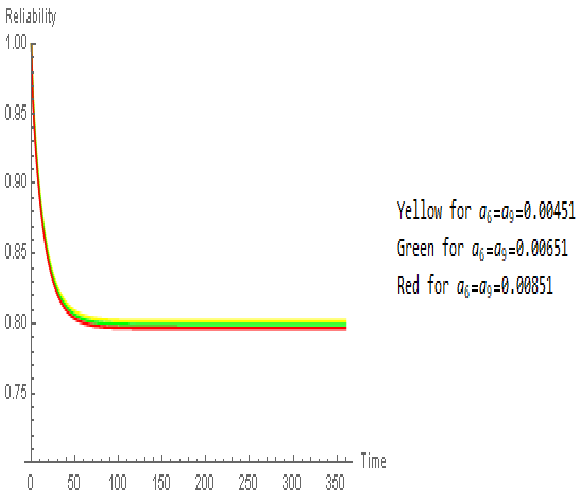

Fig.-6

***(vii) Effect of failure rate of Screw conveyor on reliability of the system*:**

In Table-7, The reliability of the system is studied by varying the failure rate of the screw conveyor as: $a_7=0.0045,.0065,.0085,a_1=0.0038,a_2=0.0057,a_3=0.0073,a_4=0.0048,a_5=0.0043,a_6=a_9=0.00451,a_7=0.0045,a_8=a_4=0.0048,b_1=0.52,b_2=0.073,b_3=0.048,b_4=0.92,b_5=0.089,b_6=0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99$;are kept fixed. We observed that the reliability of the screw conveyor is approximately 80%.

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Table 7: Effect of failure rate of screw conveyor on reliability of the system.

a_7 / t	0.0045	0.0065	0.0085
30	0.8264062	0.8263402	0.8262764
60	0.8057312	0.8056661	0.8056034
90	0.8025521	0.8024871	0.8024248
120	0.8020015	0.8019366	0.8018743
150	0.8018990	0.8018340	0.8017717
180	0.8018791	0.8018142	0.8017518
210	0.8018752	0.8018102	0.8017479
240	0.8018744	0.8018095	0.8017471
270	0.8018742	0.8018093	0.8017470
300	0.8018742	0.8018093	0.8017469
330	0.8018742	0.8018093	0.8017469
360	0.8018742	0.8018093	0.8017469

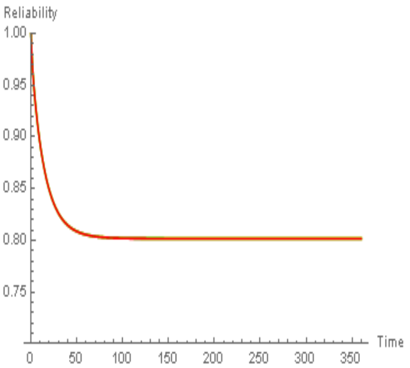

Fig.-7

***(viii) Effect of repair rate of Elevator on reliability of the system*:**

In Table-8, The reliability of the system is studied by varying the repair rate of the elevator as; b_1=0.52, 0.72, 0.92,anda_1=0.0038,a_2=0.0057,a_3=0.00730,a_4=0.0048 ,a_5=0.0043,a_6=0.00451,a_7=0.0045,a_8=a_4=0.0048,a_9= a_6=0.00451,b_2=0.073,b_3=0.048,b_4=0.92,b_5=0.089,b_6 =0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99 are kept fixed. We observed that the reliability of the elevator is approximately 80%.

Table 8: Effect of repair rate of Elevator on reliability of the system.

b_1 / t	0.52	0.72	0.92
30	0.8264062	0.8278055	0.8285951
60	0.8057312	0.8070501	0.8077970
90	0.8025521	0.8038611	0.8046028
120	0.8020015	0.8033092	0.8040501
150	0.8018990	0.8032064	0.8039472
180	0.8018791	0.8031865	0.8039273
210	0.8018752	0.8031826	0.8039234
240	0.8018744	0.8031818	0.8039226
270	0.8018742	0.8031816	0.8039224
300	0.8018742	0.8031816	0.8039224
330	0.8018742	0.8031816	0.8039224
360	0.8018742	0.8031816	0.8039224

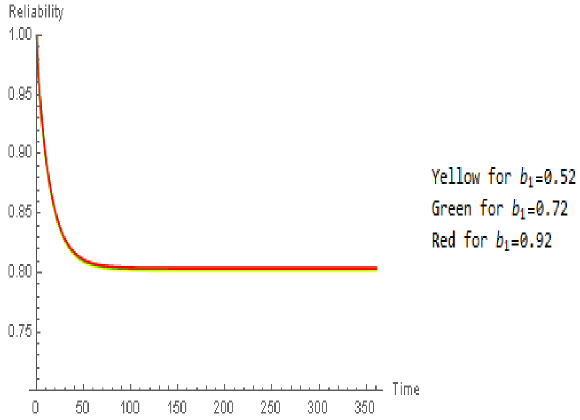

Fig.-8

***(ix) Effect of repair rate of Grinder on reliability of the system*:**

In Table-9, The reliability of the system is studied by varying the repair rate of the grinder as; b_2=0.073, 0.083, 0.093anda_1=0.0038,a_2=0.0057,a_3=0.00730,a_4=0.0048,a_5=0.0043,a_6=0.00451,a_7=0.0045,a_8=a_4=0.0048,a_9 =a_6=0.00451,b_1=0.52,b_3=0.048,b_4=0.92,b_5=0.089,b_6 =0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99 are kept fixed. We observed that the reliability of the grinder is approximately 81%.

Table 9: Effect of repair rate of Grinder on reliability of the system.

b_2 / t	0.073	0.083	0.093
30	0.8264062	0.8313415	0.8355675
60	0.8057312	0.8118312	0.8167453

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90	0.8025521	0.8086819	0.8135625
120	0.8020015	0.8081068	0.8129635
150	0.8018990	0.8079962	0.8128471
180	0.8018791	0.8079746	0.8128243
210	0.8018752	0.8079703	0.8128199
240	0.8018744	0.8079694	0.8128190
270	0.8018742	0.8079692	0.8128188
300	0.8018742	0.8079692	0.8128188
330	0.8018742	0.8079692	0.8128188
360	0.8018742	0.8079692	0.8128188

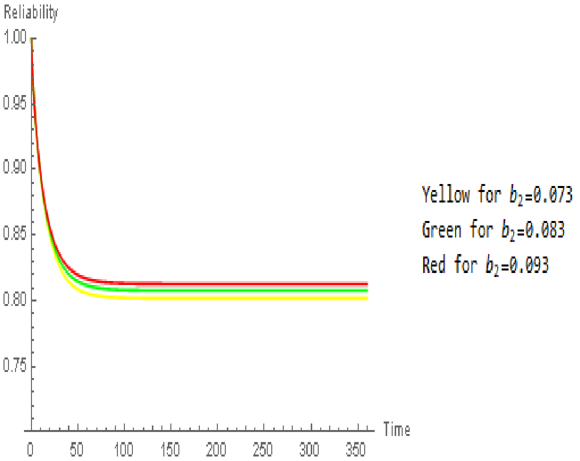

Fig.-9

***(x) Effect of repair rate of Hopper on reliability of the system*:**

In Table-10, The reliability of the system is studied by varying the repair rate of the hopper as,; b_3=0.048, 0.068, 0.088anda_1=0.0038,a_2=0.0057,a_3=0.00730,a_4=0.0048,a_5=0.0043,a_6=0.00451,a_7=0.0045,a_8=a_4=0.0048,a_9=a_6=0.00451,b_1=0.52,b_2=0.073,b_4=0.92,b_5=0.089,b_6=0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99 are kept fixed. We observed that the reliability of the hopper is approximately 83%.

Table 10: Effect of repair rate of Grinder on reliability of the system.

b_3 / t	**0.048**	**0.068**	**0.088**
30	0.8264062	0.8443387	0.8573237
60	0.8057312	0.8327709	0.8495022
90	0.8025521	0.8317970	0.8489753
120	0.8020015	0.8317139	0.8489363
150	0.8018990	0.8317067	0.8489331
180	0.8018791	0.8317060	0.8489328
210	0.8018752	0.8317060	0.8489328
240	0.8018744	0.8317060	0.8489328
270	0.8018742	0.8317060	0.8489328
300	0.8018742	0.8317060	0.8489328
330	0.8018742	0.8317060	0.8489328
360	0.8018742	0.8317060	0.8489328

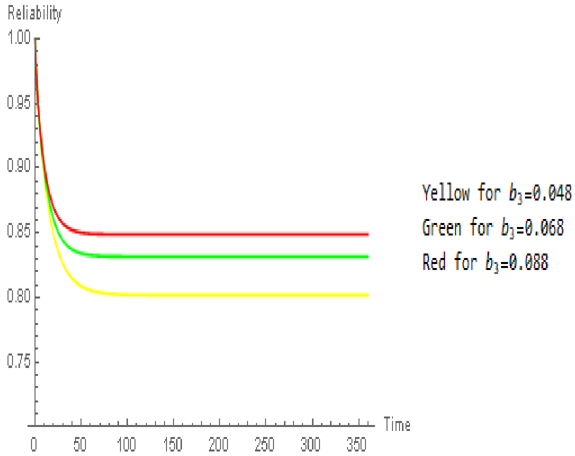

Fig.-10

***(xi) Effect of repair rate of mixer on reliability of the system*:**

In Table-11, The reliability of the system is studied by varying the repair rate of the mixer as;b_4=0.92,.95,.98and a_1=0.0038,a_2=0.0057,a_3=0.00730,a_4=0.0048,a_5=0.0043,a_6=0.00451,a_7=0.0045,a_8=a_4=0.0048,a_9=a_6=0.00451,b_1=0.52,b_2=0.073, b_3=0.048,b_5=0.089,b_6=0.99,b_7=0.092, b_9=b_6=0.99 are kept fixed. We observed that the reliability of the mixer is approximately 80%.

Table 11: Effect of repair rate of mixer on reliability of the system.

b_4 / t	**0.92**	**0.95**	**0.98**
30	0.8264062	0.8264164	0.8264259
60	0.8057312	0.8057414	0.8057509
90	0.8025521	0.8025621	0.8025715
120	0.8020015	0.8020116	0.8020210
150	0.8018990	0.8019090	0.8019184
180	0.8018791	0.8018891	0.8018985
210	0.8018752	0.8018852	0.8018946
240	0.8018744	0.8018844	0.8018938

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270	0.8018742	0.8018842	0.8018936
300	0.8018742	0.8018842	0.8018936
330	0.8018742	0.8018842	0.8018936
360	0.8018742	0.8018842	0.8018936

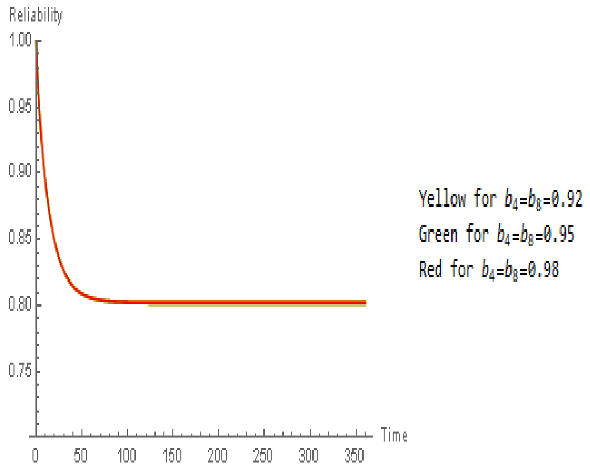

Fig.-11

***(xii) Effect of repair rate of Winch on reliability of the system*:**

In Table-12, The reliability of the system is studied by varying the repair rate of the winch as; b_5=0.089,.094,.099anda_1=0.0038,a_2=0.0057,a_3=0.00730,a_4=0.0048,a_5=0.0043,a_6=0.00451,a_7=0.0045,a_8=a_4=0.0048,a_9=a_6=0.00451,b_1=0.52,b_2=0.073,b_3=0.048,b_4=0.92,b_6=0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99 are kept fixed. We observed that the reliability of the winch is approximately 80%.

Table 12: Effect of repair rate of winch on reliability of the system.

b_5 / t	**0.089**	**0.094**	**0.099**
30	0.8264062	0.8264137	0.8264207
60	0.8057312	0.8057400	0.8057479
90	0.8025521	0.8025607	0.8025685
120	0.8020015	0.8020101	0.8020179
150	0.8018990	0.8019075	0.8019153
180	0.8018791	0.8018877	0.8018954
210	0.8018752	0.8018838	0.8018915
240	0.8018744	0.8018830	0.8018907
270	0.8018742	0.8018828	0.8018905
300	0.8018742	0.8018828	0.8018905
330	0.8018742	0.8018828	0.8018905
360	0.8018742	0.8018828	0.8018905

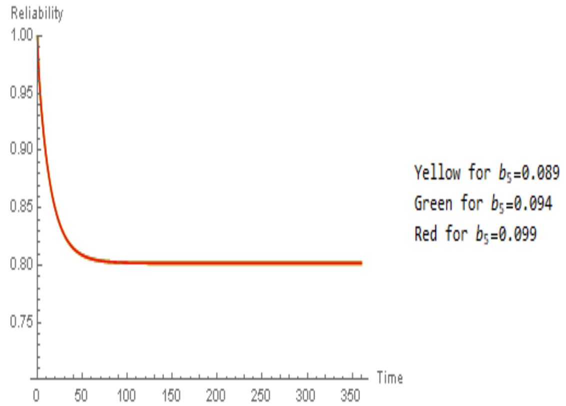

Fig.-12

***(xiii) Effect of repair rate of Palletiser on reliability of the system*:**

In Table-13, The reliability of the system is studied by varying the repair rate of the palletiser as; b_9=b_6=0.99,.9949,.9998anda_1=0.0038,a_2=0.0057,a_3=0.00730,a_4=0.0048,a_5=0.0043,a_6=0.00451,a_7=0.0045,a_8=a_4=0.0048,a_9=a_6=0.00451,b_1=0.52,b_2=0.073, b_3=0.048,b_4=0.92, b_5=0.089, b_7=0.092,b_8=b_4=0.92 are kept fixed. We observed that the reliability of the palletiser is approximately 80%.

Table 13: Effect of repair rate of palletiser on reliability of the system.

b_6 / t	**0.99**	**0.9949**	**0.9998**
30	0.8264062	0.8264369	0.8264673
60	0.8057312	0.8057604	0.8057892
90	0.8025521	0.8025810	0.8026096
120	0.8020015	0.8020304	0.8020590
150	0.8018990	0.8019278	0.8019564
180	0.8018791	0.8019080	0.8019365
210	0.8018752	0.8019040	0.8019326
240	0.8018744	0.8019033	0.8019318
270	0.8018742	0.8019031	0.8019317
300	0.8018742	0.8019031	0.8019316
330	0.8018742	0.8019031	0.8019316
360	0.8018742	0.8019031	0.8019316

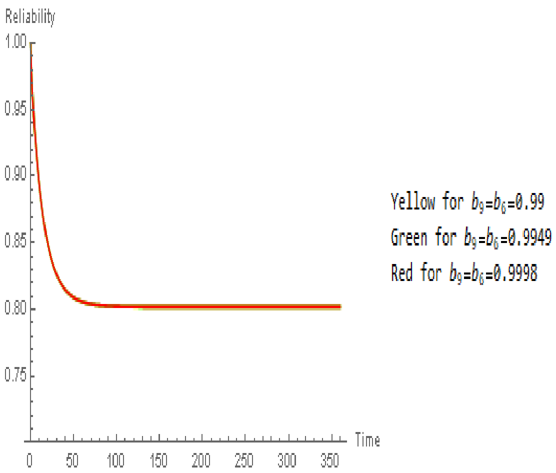

Fig.-13

***(xiv)Effect of repair rate of Screw conveyor on reliability of the system*:**

In Table-14, The reliability of the system is studied by varying the repair rate of the screw conveyoras; b_7=0.092,.095,.098anda_1=0.0038,a_2=0.0057,a_3=0.00730,a_4=0.0048,a_5=0.0043,a_6=0.00451,a_7=0.0045,a_8=a_4=0.0048,a_9=a_6=0.00451,b_1=0.52,b_2=0.073,b_3=0.048,b_4=0.92,b_5=0.089,b_6=0.99,b_7=0.092,b_8=b_4=0.92,b_9=b_6=0.99 are kept fixed. We observed that the reliability of the screw conveyor is approximately 80%.

Table 14: Effect of repair rate of screw conveyor on reliability of the system.

b_7 / t	0.092	0.095	0.098
30	0.8264062	0.8264101	0.8264138
60	0.8057312	0.8057359	0.8057402
90	0.8025521	0.8025568	0.8025612
120	0.8020015	0.8020063	0.8020107
150	0.8018990	0.8019037	0.8019081
180	0.8018791	0.8018838	0.8018883
210	0.8018752	0.8018800	0.8018843
240	0.8018744	0.8018791	0.8018836
270	0.8018742	0.8018790	0.8018834
300	0.8018742	0.8018789	0.8018834
330	0.8018742	0.8018789	0.8018834
360	0.8018742	0.8018789	0.8018834

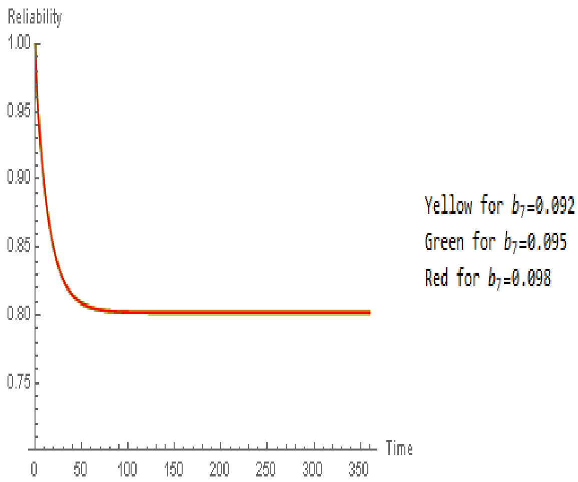

Fig.-14

5. Conclusion:

In the current paper, we accent the application of CAS Mathematica to analysed the variation of the reliability of the cattle feed plant. We analysed the variation of failure and repair rate on reliability of each unit of the system and observed that Reliability of system decreases with increase in failure rate and increases with increase in repair rate and after certain limit (270 days) it becomes constant. Mathematica is not only method of better accuracy butalso, it gives individual values of P_1, P_2………P_{13} at point t even for complex models which is not possible by other methods for complex modeling. we solvedthe system for transient state. The optimum reliability achieved is nearly 80% with best fitting of failure and repair rates of all subsystems of plants. Such results might be useful for plant owners for enhancement of performance of the cattle feed plant. Research work could be extended to optimization problem by applying particle swarm optimization, ant colony optimization and others, to enhance the performance of the system and also for betterment of plant personnel.

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