

BEHAVIOUR ANALYSIS OF RICE MANUFACTURING PLANT

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CERTIFICATE

I hereby certify that the work which is being presented in thesis entitled **“Behaviour Analysis of Rice Manufacturing Plant”** in partial fulfilment of the requirements for the award of degree of Master of Science, School of Mathematics and Computer Applications, Thapar Institute of Engineering and Technology, Patiala is an authentic record of my own work carried out under the supervision of Dr. A. K. Lal.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

Harpreet Kaur
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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.



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ABSTRACT

The Thesis titled “BEHAVIOUR ANALYSIS OF RICE MANUFACTURING PLANT” is an endeavour to build up a mathematical model for evaluator the reliability and availability of rice manufacturing plant.

In the present study, we discuss the reliability of rice manufacturing plant – KRBL Limited Company located in Bhasaur near Dhuri. The entire process includes sub-systems, i.e Storage Bin, Cleaner Machine, Destoner Machine, Whitener Machine, Grader, Sortex Machine, Packing Machine. The mathematical model of this manufacturing industry has been developed with the help of Markovian method. The Chapman-Kolomorgov differential equations. Thus obtained has been solved numerically using Runge-Kutta forth order method for various choices of failure and repair rates of the sub-systems for determines reliability of this manufacturing plant. By using Gauss elimination method we also find the availability of system for the various combination of failure and repair rates of this plant. The outcome of hazard rates (failure rates) and repair rates on the reliability of the system has been studied in detail with the help form tables and graph.

CHAPTER 1
INTRODUCTION

In today's world population increases day-by-day, therefore many social and technological improvements are needed. Overall, these technological improvements cause new and more complex systems to be developed day-by-day.

At the same time, one of the important characteristics of a product is its achievement within the specified time. To study and analyse the performance of a system a time based concept, known as Reliability is used frequently in the literature. Reliability is very old concept and is most important characteristics used by client.

Reliability was first acknowledged as an important approach during 2nd world war. The initial steps in this path were taken in U.S.A by creating Joint Army and Navy (JAN) in June 1943.

1.1 Literature Review

Conscious of the importance of the subject, reliability has been produced and a good contribution has been made by a number of authors. In 1960, first textbook on reliability written by Dummer and Griffen appeared in literature. Sathaye et al. (2000) discussed the availability models in practice. Lambert (2000) has considered the overview of small-scale milk collections and processing plant. Habchi (2002) discussed an improved method of reliability assessment for suspended tests Gunes and Deveci (2002) studied the reliability of service systems and its application in student office.

When a system consists of more than one unit there is a possibility for complete failure of the system due to single cause. Such failures are termed as common cause failures and these are highly effective as far as reliability analysis of the system is considered. Gagloft (1975) defined the common cause failure in a system when multiple units or components at any instant fail due to single common cause. Gupta (2003) has discussed Mathematical analysis of reliability and availability of some process industries. Using numerical approach Gupta et al.

(2005) investigated the behavioral study of the Cement manufacturing plant Pawan et al. (2007) also analysed the Reliability and Availability of Serial Processes of Plastic – Pipe Manufacturing Plant – a case study using matrix calculus method and Gupta et al. has discussed Numerical analysis of reliability of serial processes in butter-oil processing plant. Lia et al. (2017) discussed reliability analysis of combination method. Gupta (2019) has considered stochastic modelling multi-state systems subject to failure mechanism dependence based on a and availability analysis of a critical engineering system. Devendra et al. (2019) discussed reliability, availability and maintainability analysis of a cement plant. Lal, et al. (2013) has studied behavioral analysis of piston manufacturing plant through stochastic models. Gupta and Vinodiya (2018) analysed of reliability of a two non identical units cold standby repairable system having two types of failure. Parashar and Bhardwaj (2013) investigated a comparative study of profit analysis of two reliability models on a two unit PLC system. Rachna et al. (2019) has considered analysis of a three unit system with demand dependent operability of units and Shakuntla et al. (2019) also analysis of non-markovian process by the inclusion of supplementary variables.

Although, various authors discussed the reliability and availability analysis of different types of manufacturing process but not satisfactory work has been done so far for rice plant.

1.2 Definition and basic concepts

RELIABILITY

The capability for failure free operation for a definite period of time under the given operating conditions and for minimum time cost for repair and preventive maintenance is called Reliability of a system.

Reliability can be thought of as the probability of the survival of a component until time t . Its complement is the probability of failure before or at time t . If we define a random variable T as the time to failure, then

$$R(t) = P(T > t)$$

where $R(t)$ is the reliability.

AVAILABILITY

This is the probability that the system will almost certainly work inside the tolerance at a given moment of time.

Failure rate (Hazard rate)

Failure rate (Hazard rate) is said to be in the terms of number of failures per unit time, for example, failures per year etc. Failure rate is calculated as the ratio of number of failures of the items undergoing test to the test time, i.e.,

$$\alpha = \frac{N_f}{t} \tag{1}$$

where, α = failure rate (Hazard rate) , N_f = number of failures during test interval and t = total test time.

Repair rate

Repair rate is said to be in terms of number of repairs per unit time, for example, repair per year etc. Repair rate is calculated as the ratio of number of repairs of the items undergoing test of the test time, i.e.,

$$\beta = \frac{N_r}{t} \tag{2}$$

where, β = repair rate, N_r = number of repairs during test interval and t = total test time.

Mean time to failures (MTTF)

Mean time to failures (MTTF) is the main parameter in reliability theory. MTTF is the statistical *average* time before failure of the system. When failure rate is fairly constant, then MTTF is defined as,

$$\text{MTTF} = \int_0^{\infty} R(t) dt \quad (3)$$

where, $R(t)$ is the reliability of the system.

MARKOV PROCESS

A stochastic process in a physical system (S) is known as Markov process if the occurrence of any future state of the system is independent of any past state and depends only on the present state. In the Markov process, we deal with two random variables either one of which can be discrete or continuous. Generally, one of the random variables refers to the state of a physical system and the other random variable refers to time, Srinath (2002).

1.3 Summary of the present work

In the present study, we discuss the reliability of rice manufacturing plant – KRBL Limited Company located in Bhasaur near Dhuri. The entire process includes sub-systems, i.e Storage Bin, Cleaner Machine, Destoner Machine, Whitener Machine, Grader, Sortex Machine, Packing Machine. The mathematical model of this manufacturing industry has been developed with the help of Markovian method. The Chapman-Kolomorgov differential equations. Thus obtained has been solved numerically using Runge-Kutta forth order method for various choices of failure and repair rates of the sub-systems for determines reliability of this manufacturing plant. By using Gauss elimination method we also

find the availability of system for the various combination of failure and repair rates of this plant. The outcome of hazard rates (failure rates) and repair rates on the reliability of the system has been studied in detail with the help form tables and graph.

CHAPTER 2

RELIABILITY ANALYSIS OF THE RICE MANUFACTURING PLANT

In this chapter, the reliability of rice manufacturing plant have been discussed with the actual information taken from KRBL limited industry. This chapter is organised as follows:

A brief information to rice manufacturing machine has been discussed in Section 2.1. In this Section, we also discussed the process of rice milling with the help of flow chat. The assumptions on which present study is based are explained in Section 2.2. Mathematical model for reliability of rice manufacturing plant has been developed in Section 2.3. Behaviour study of this plant has been discussed in Section 2.4 Certain conclusion based on the present analysis has finally been drawn with the help of tables and graph in section 2.5.

2.1 INTRODUCTION TO RICE MANUFACTURING PROCESS:

Over the years, from agricultural commodities such as wheat, cotton and oil as our core business, we changed our main focus to rice. Since 1947 until today, we have relocated and restructured our company again and again. The main components of paddy or rice grain are husk and brown rice. Brown rice includes outer layer and the edible portion. To get the edible portion of rice, rice milling is used in which husk and bran removed. The process has to be done carefully to avoid the breakage of the cores of rice. According to various rice mills the by products emerges in mixed form. The main purpose of the Rice mill is to remove husk, bran, clean and polish to obtain edible portion. In order to study reliability and availability of manufacturing plant, we have chosen KRBL Limited industry which produces rice. A brief description of various components of this plant is as follows :

Paddy to Rice converter basically consists of seven components namely :

1. Storage Bin, 2. Cleaner Machine, 3. Destoner Machine, 4. Whitener Machine, 5. Length Grader, 6. Sortex Machine, 7. Packing Machine

The brief description of these sub-systems is as follows :

1. Storage Bin (A) : Storage Bin is a container which contains raw materials. It is used to store the paddy grain. In the Storage Bin grains are safely stored for long time. This system results in major failure.

2. Cleaner Machine (B) : Cleaner Machine is best suited for cleaning and classified the grain. Cleaner Machine separates rice, soybean, corn and separates big or small impurities and stones from grain. It is the best machine for grain processing plant. According to its use, there are three types of cleaner machine i.e. Vibration Cleaner, Combined Cleaner and Rotary Paddy Cleaner . This system results in major failure.

3. Destoner Machine (C) : A Destoner Machine is that machine which is used to separates stones, dolts from soil ridges and other impurities from rice. It removes bulk material from rice with less than 3mm in size and it is used in many mills for instance wheat mill, rice mill etc. This system results in major failure.

4. Whitener Machine (D) : Whitener machine is used to polishing the cores of the rice to change their appearance and it converts from brown rice into white rice and also it removes part of brain layer and germs from rice. It helps to avoid spoilage and increase its storage life. After the polishing of rice it gives white and shiny appearance. This system results in major failure.

5. Grader (E) :

(i) Thickness Grader : Grader is used to separate grains of different thickness. For removing oversized and undersized grains, the material is passed through

cylindrical screens. This machine is very useful for this work. This system results in major failure.

(ii) Length Grader : Length Grader is used to separate grains of different length. This machine is usually used for any types of rice like Basmati Rice, Steam Rice, Raw Rice etc. The material is passed through rotating cylinders. Also it can be used to separate broken grains from the overall grains. This system results in major failure.

6. Sortex Machine (F) : Sortex Machine is commonly used in sorting grains. The main function of sorting machine is to separate rice grains by their colours. In colour sorter machine, we put the rice mixture into the hopper in which it travelled through an elevator belt on the top of the machine, from which it will run down along chutes in the colour sorter, streamlining their flow from which they scan by the CCD sensors. After that, the camera perceives any defect in colour, it ordered ejectors fitted in the machine to open the nozzle. This system results in major failure.

7. Packing Machine (G) : Packing machines are used to pack various types of rice grains. Packing procedure includes paper, ink, printing material etc. In this procedure firstly the material is put into plastic bags, the capacity of bags is depends upon the quantity of rice. After that, the required print is done by the machine. In the last step the heat seal is done by the machine. This system results in major failure.

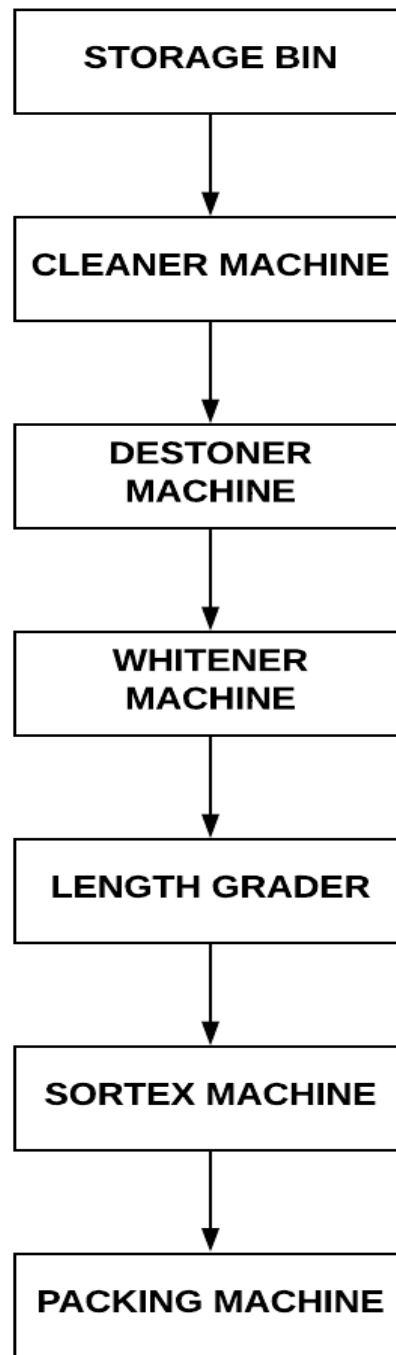


Fig 2.1 - Flow Chart of Rice Plant

2.2 Notations

The transition diagram for this system is shown in Fig 2.2. The following notations are used throughout in the study:

A, B ,C ,D ,E,F,G signify that systems are working in good states.

α_i (i=1 to 7) : Failure rates of sub-systems A, B, C, D, E,F,G.

β_i (i=1 to 7) : Repair rates of sub-systems A, B, C, D, E,F,G.

$P_j(t)$ Probability that the system is in j^{th} state at time t,(j=1,2,3...7).

a, b, c, d, e, f, g represent the failed states of the sub-systems A, B, C, D, E,F,G respectively.

Assumptions

The following assumptions are considered to discuss the reliability analysis of rice plant.

(i) Failure rate (Hazard rate) and Repair rate are independent with each other and their unit is per days.

(ii) There are no simultaneous failures among the sub-systems.

(iii) Repaired components are treated as new one.

(iv) Repair and failure rates of sub-system are assumed to be constant.

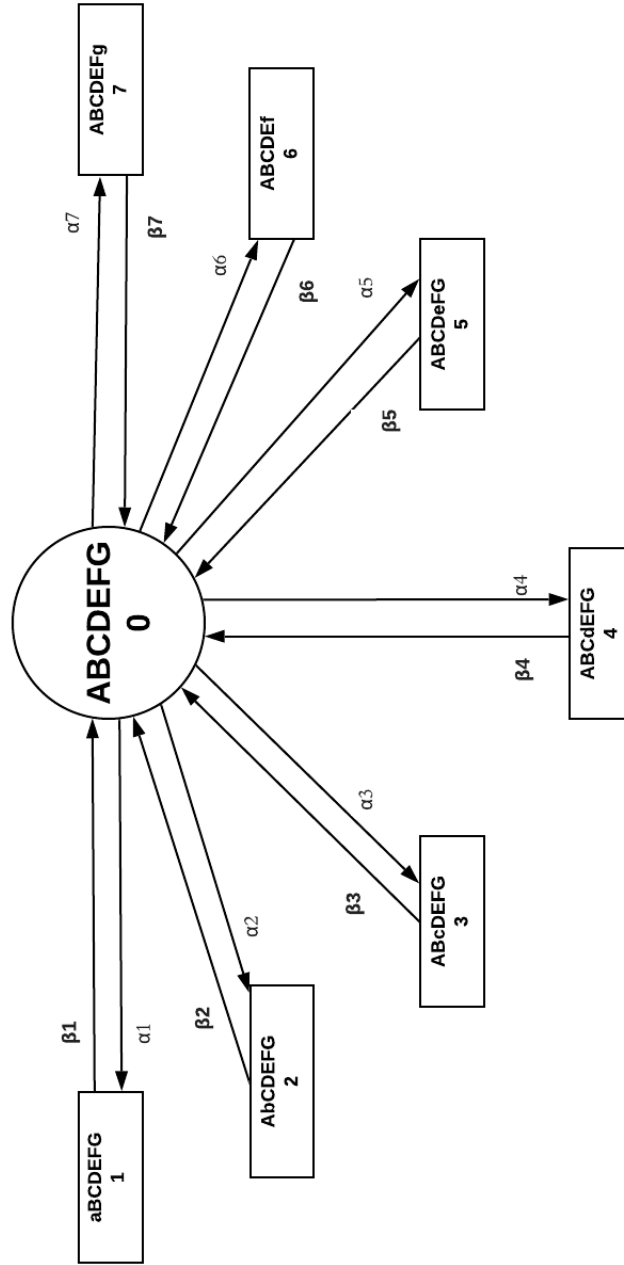
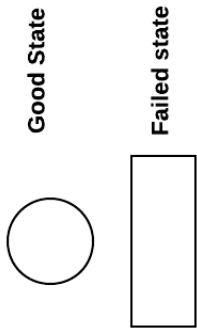


Fig 2.2: Transition Diagram for sub-system

2.3 MATHEMATICAL FORMULATION OF THE SYSTEM

2.3.1 TRANSIENT STATE

In the transient state, probability considerations give the following first order differential equations associated with the system transition diagram.

$$P_0'(t) + \lambda_1 P_0(t) = \beta_1 P_1(t) + \beta_2 P_2(t) + \beta_3 P_3(t) + \beta_4 P_4(t) + \beta_5 P_5(t) + \beta_6 P_6(t) + \beta_7 P_7(t) \quad (2.1)$$

$$P_1'(t) + \beta_1 P_1(t) = \alpha_1 P_0(t) \quad (2.2)$$

$$P_2'(t) + \beta_2 P_2(t) = \alpha_2 P_0(t) \quad (2.3)$$

$$P_3'(t) + \beta_3 P_3(t) = \alpha_3 P_0(t) \quad (2.4)$$

$$P_4'(t) + \beta_4 P_4(t) = \alpha_4 P_0(t) \quad (2.5)$$

$$P_5'(t) + \beta_5 P_5(t) = \alpha_5 P_0(t) \quad (2.6)$$

$$P_6'(t) + \beta_6 P_6(t) = \alpha_6 P_0(t) \quad (2.7)$$

$$P_7'(t) + \beta_7 P_7(t) = \alpha_7 P_0(t) \quad (2.8)$$

Where,

$$\lambda_1 = \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 + \alpha_6 + \alpha_7$$

with the initial conditions $P_0(0) = 1$ and 0 otherwise. (2.9)

This Chapman-Kolomorgov differential difference equations have been formulated by using mnemonic rule on the transition diagram Fig 2.2. The reliability of the system can be obtained by using the relation,

$$R(t) = P_0(t) \quad (2.10)$$

2.4 BEHAVIOUR STUDY

2.4.1 TRANSIENT STATE

The system of differential equations (2.1-2.8) with initial conditions (2.9) has been solved numerically using Runge-Kutta fourth order method. Getting the data for hazard rates (failure rates) and repair rates of the sub-systems per day, the calculations have been performed up to 360 days for various values of hazard rates and repair rates of the sub-systems by assuming the step size of iteration as $h=0.005$, as one day. The reliability is affected, if the hazard rates and repair rates are altered.

(i) Effect of hazard rate (failure rate) of Storage Bin (α_1) on reliability of the system: The reliability of the system is computed by using the following combinations of failure and repair rates. Reliability is presented in Table 2.1(a) The parameter α_1 is considered at the level of 0.005, 0.007, 0.009, 0.011, 0.013 and other parameters are taken as: $\alpha_2 = 0.0013$, $\alpha_3 = 0.0027$, $\alpha_4 = 0.0027$, $\alpha_5 = 0.0054$, $\alpha_6 = 0.0027$, $\alpha_7 = 0.2$, $\beta_1 = 8$, $\beta_2 = 3.8$, $\beta_3 = 48$, $\beta_4 = 1$, $\beta_5 = 12$, $\beta_6 = 12$, $\beta_7 = 2.1238$. The table shows that the effect of failure rate of storage bin (α_1) on the reliability of the system. Reliability of the system decreases with estimate 0.09% but the reliability remains same with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(a): EFFECT OF HAZARD RATE (FAILURE RATE) STORAGE BIN (α_1) ON RELIABILITY OF THE SYSTEM

$\alpha_1 \rightarrow$ Days↓	0.005	0.007	0.009	0.011	0.013
30	0.910275	0.910275	0.909861	0.909654	0.909447
60	0.910275	0.910275	0.909861	0.909654	0.909447
90	0.910275	0.910275	0.909861	0.909654	0.909447
120	0.910275	0.910275	0.909861	0.909654	0.909447
150	0.910275	0.910275	0.909861	0.909654	0.909447
180	0.910275	0.910275	0.909861	0.909654	0.909447
210	0.910275	0.910275	0.909861	0.909654	0.909447
240	0.910275	0.910275	0.909861	0.909654	0.909447
270	0.910275	0.910275	0.909861	0.909654	0.909447
300	0.910275	0.910275	0.909861	0.909654	0.909447
330	0.910275	0.910275	0.909861	0.909654	0.909447
360	0.910275	0.910275	0.909861	0.909654	0.909447
MTTF	291.2879	291.2217	291.1554	291.0892	291.0230

(ii) Effect of hazard rate (failure rate) of Cleaner Machine (α_2) on reliability of the system: Result of hazard rate (failure rate) of sub-system, Cleaning Machine on the reliability of the system with varying its values as $\alpha_2 = 0.0013, 0.0033, 0.0053, 0.0073, 0.0093$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. Table 2.1(b) shows that the result of cleaning machine (α_2) on the reliability of the system. Reliability of the system decreases with estimate 0.191% but the reliability remains same with the increments the time

from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(b): EFFECT OF HAZARD RATE (FAILURE RATE) HUSKING (α_2) ON RELIABILITY OF THE SYSTEM

$\alpha_2 \rightarrow$ Days \downarrow	0.0013	0.0033	0.0053	0.0073	0.0093
30	0.910275	0.909839	0.909404	0.908963	0.908534
60	0.910275	0.909839	0.909404	0.908963	0.908534
90	0.910275	0.909839	0.909404	0.908963	0.908534
120	0.910275	0.909839	0.909404	0.908963	0.908534
150	0.910275	0.909839	0.909404	0.908963	0.908534
180	0.910275	0.909839	0.909404	0.908963	0.908534
210	0.910275	0.909839	0.909404	0.908963	0.908534
240	0.910275	0.909839	0.909404	0.908963	0.908534
270	0.910275	0.909839	0.909404	0.908963	0.908534
300	0.910275	0.909839	0.909404	0.908963	0.908534
330	0.910275	0.909839	0.909404	0.908963	0.908534
360	0.910275	0.909839	0.909404	0.908963	0.908534
MTTF	291.2879	291.1484	291.0091	290.8699	290.7308

(iii) Effect of hazard rate (failure rate) of Destoner Machine (α_3) on reliability of the system: Result of hazard rate (failure rate) of sub-system, Destoner Machine on the reliability of the system with varying its values as $\alpha_3 = 0.0027, 0.0047, 0.0067, 0.0087, 0.0107$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. Table 2.1(c) shows that the

result of destoner machine (α_3) on the reliability of the system. Reliability of the system decreases with estimate 0.015% but the reliability remains constant with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(c): EFFECT OF HAZARD RATE (FAILURE RATE) DESTONER MACHINE (α_3) ON RELIABILITY OF THE SYSTEM

$\alpha_3 \rightarrow$ Days \downarrow	0.0027	0.0047	0.0067	0.0087	0.0107
30	0.910275	0.910240	0.910206	0.910171	0.910137
60	0.910275	0.910240	0.910206	0.910171	0.910137
90	0.910275	0.910240	0.910206	0.910171	0.910137
120	0.910275	0.910240	0.910206	0.910171	0.910137
150	0.910275	0.910240	0.910206	0.910171	0.910137
180	0.910275	0.910240	0.910206	0.910171	0.910137
210	0.910275	0.910240	0.910206	0.910171	0.910137
240	0.910275	0.910240	0.910206	0.910171	0.910137
270	0.910275	0.910240	0.910206	0.910171	0.910137
300	0.910275	0.910240	0.910206	0.910171	0.910137
330	0.910275	0.910240	0.910206	0.910171	0.910137
360	0.910275	0.910240	0.910206	0.910171	0.910137
MTTF	291.2879	291.2769	291.265	291.254	291.2437

(iv) Effect of hazard rate (failure rate) of Whitener Machine (α_4) on reliability of the system: Now we calculate the reliability of the system with the varying failure rate of whitener machine. We have take $\alpha_4 = 0.0027, 0.0047, 0.0067,$

0.0087, 0.0107 and other parameters are taken as: $\alpha_1 = 0.005$, $\alpha_2 = 0.0013$, $\alpha_3 = 0.0027$, $\alpha_5 = 0.0054$, $\alpha_6 = 0.0027$, $\alpha_7 = 0.2$, $\beta_1 = 8$, $\beta_2 = 3.8$, $\beta_3 = 48$, $\beta_4 = 1$, $\beta_5 = 12$, $\beta_6 = 12$, $\beta_7 = 2.1238$. Table 2.1(d) shows that the result of whitener machine (α_4) on the reliability of the system. Reliability of the system decreases with estimate 0.72% but the reliability remains same with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(d): EFFECT OF HAZARD RATE (FAILURE RATE) WHITENER MACHINE (α_4) ON RELIABILITY OF THE SYSTEM

$\alpha_4 \rightarrow$ Days \downarrow	0.0027	0.0047	0.0067	0.0087	0.0107
30	0.910275	0.908621	0.906973	0.905330	0.903694
60	0.910275	0.908621	0.906973	0.905330	0.903694
90	0.910275	0.908621	0.906973	0.905330	0.903694
120	0.910275	0.908621	0.906973	0.905330	0.903694
150	0.910275	0.908621	0.906973	0.905330	0.903694
180	0.910275	0.908621	0.906973	0.905330	0.903694
210	0.910275	0.908621	0.906973	0.905330	0.903694
240	0.910275	0.908621	0.906973	0.905330	0.903694
270	0.910275	0.908621	0.906973	0.905330	0.903694
300	0.910275	0.908621	0.906973	0.905330	0.903694
330	0.910275	0.908621	0.906973	0.905330	0.903694
360	0.910275	0.908621	0.906973	0.905330	0.903694
MTTF	291.2879	290.7586	290.2312	289.7057	289.1821

(v) Effect of hazard rate (failure rate) of Length Grader (α_5) on reliability of the system: Result of hazard rate (failure rate) of sub-system, namely, Length Grader on the reliability of the system with varying its values as $\alpha_5 = 0.0054, 0.0074, 0.0094, 0.0114, 0.0134$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. Table 2.1(e) shows that the result of cleaning machine (α_2) on the reliability of the system. Reliability of the system decreases with estimate 0.06% but the reliability remains same with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(e): EFFECT OF HAZARD RATE (FAILURE RATE) LENGTH GRADER (α_5) ON RELIABILITY OF THE SYSTEM

$\alpha_5 \rightarrow$ Days \downarrow	0.0054	0.0074	0.0094	0.0114	0.0134
30	0.910275	0.910137	0.909999	0.909861	0.909723
60	0.910275	0.910137	0.909999	0.909861	0.909723
90	0.910275	0.910137	0.909999	0.909861	0.909723
120	0.910275	0.910137	0.909999	0.909861	0.909723
150	0.910275	0.910137	0.909999	0.909861	0.909723
180	0.910275	0.910137	0.909999	0.909861	0.909723
210	0.910275	0.910137	0.909999	0.909861	0.909723
240	0.910275	0.910137	0.909999	0.909861	0.909723
270	0.910275	0.910137	0.909999	0.909861	0.909723
300	0.910275	0.910137	0.909999	0.909861	0.909723
330	0.910275	0.910137	0.909999	0.909861	0.909723
360	0.910275	0.910137	0.909999	0.909861	0.909723
MTTF	291.2879	291.2437	291.1996	291.1554	291.1113

(vi) Effect of hazard rate (failure rate) of Sortex Machine (α_6) on reliability of the system: Now we calculate the reliability of the system with the varying failure rate of Sortex machine. We have take $\alpha_6 = 0.0027, 0.0047, 0.0067, 0.0087, 0.0107$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. Table 2.1(f) shows that the result of sortex machine (α_6) on the reliability of the system. Reliability of the system decreases with estimate 0.06% but the reliability remains same with the increments the time from 30 to 3600

hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(f): EFFECT OF HAZARD RATE (FAILURE RATE) (α_6) SORTEX MACHINE ON RELIABILITY OF THE SYSTEM

$\alpha_6 \rightarrow$ Days \downarrow	0.0027	0.0047	0.0067	0.0087	0.0107
30	0.910275	0.910137	0.909999	0.909861	0.909723
60	0.910275	0.910137	0.909999	0.909861	0.909723
90	0.910275	0.910137	0.909999	0.909861	0.909723
120	0.910275	0.910137	0.909999	0.909861	0.909723
150	0.910275	0.910137	0.909999	0.909861	0.909723
180	0.910275	0.910137	0.909999	0.909861	0.909723
210	0.910275	0.910137	0.909999	0.909861	0.909723
240	0.910275	0.910137	0.909999	0.909861	0.909723
270	0.910275	0.910137	0.909999	0.909861	0.909723
300	0.910275	0.910137	0.909999	0.909861	0.909723
330	0.910275	0.910137	0.909999	0.909861	0.909723
360	0.910275	0.910137	0.909999	0.909861	0.909723
MTTF	291.2879	291.2437	291.1996	291.1554	291.1113

(vii) Effect of hazard rate (failure rate) of Packing Machine (α_7) on reliability of the system: Again we calculate the reliability of the system with consider the failure rates and repair rates. We have take $\alpha_7 = 0.2, 0.202, 0.204, 0.206, 0.208$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 =$

12, $\beta_7 = 2.1238$. Table 2.1(g) shows that the result of packing machine (α_7) on the reliability of the system. Reliability of the system decreases with estimate 0.34% but the reliability remains same with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(g): EFFECT OF HAZARD RATE (FAILURE RATE) (α_7) PACKING MACHINE ON RELIABILITY OF THE SYSTEM

$\alpha_7 \rightarrow$ Days \downarrow	0.2	0.202	0.204	0.206	0.208
30	0.910275	0.909495	0.908717	0.907940	0.907164
60	0.910275	0.909495	0.908717	0.907940	0.907164
90	0.910275	0.909495	0.908717	0.907940	0.907164
120	0.910275	0.909495	0.908717	0.907940	0.907164
150	0.910275	0.909495	0.908717	0.907940	0.907164
180	0.910275	0.909495	0.908717	0.907940	0.907164
210	0.910275	0.909495	0.908717	0.907940	0.907164
240	0.910275	0.909495	0.908717	0.907940	0.907164
270	0.910275	0.909495	0.908717	0.907940	0.907164
300	0.910275	0.909495	0.908717	0.907940	0.907164
330	0.910275	0.909495	0.908717	0.907940	0.907164
360	0.910275	0.909495	0.908717	0.907940	0.907164
MTTF	291.2879	291.0385	290.7894	290.5408	290.2926

(viii) Effect of Repair rate of Storage bin (β_1) on reliability of the system: The reliability of the system is computed by using the following combinations of failure and repair rates. Reliability is presented in Table 2.1(h) The parameter β_1 is considered at the level of 8, 8.2, 8.4, 8.6, 8.8 and other parameters are taken as: α_1

$= 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. The table 2.1(h) shows that the effect of failure rate of storage bin (β_1) on the reliability of the system. Reliability of the system increases with estimate 0.005% but the reliability remains constant with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(h): EFFECT OF REPAIR RATE (β_1) STORAGE BIN ON RELIABILITY OF THE SYSTEM

$\beta_1 \rightarrow$ Days \downarrow	8	8.2	8.4	8.6	8.8
30	0.910275	0.910288	0.910300	0.910311	0.910332
60	0.910275	0.910288	0.910300	0.910311	0.910332
90	0.910275	0.910288	0.910300	0.910311	0.910332
120	0.910275	0.910288	0.910300	0.910311	0.910332
150	0.910275	0.910288	0.910300	0.910311	0.910332
180	0.910275	0.910288	0.910300	0.910311	0.910332
210	0.910275	0.910288	0.910300	0.910311	0.910332
240	0.910275	0.910288	0.910300	0.910311	0.910332
270	0.910275	0.910288	0.910300	0.910311	0.910332
300	0.910275	0.910288	0.910300	0.910311	0.910332
330	0.910275	0.910288	0.910300	0.910311	0.910332
360	0.910275	0.910288	0.910300	0.910311	0.910332
MTTF	291.2879	291.2920	291.2958	291.2995	291.3030

(ix) Effect of Repair rate of Cleaner Machine (β_2) on reliability of the system:

Now we calculate the reliability of the system with the varying Repair rate of Cleaner machine. We have taken $\beta_2 = 3.8, 4, 4.2, 4.4, 4.6$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. Table 2.1(i) shows that the result of cleaner machine (β_2) on the reliability of the system. Reliability of the system increases with estimate 0.005% but the reliability remains same with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(i): EFFECT OF REPAIR RATE (β_2) CLEANER MACHINE ON RELIABILITY OF THE SYSTEM

$\beta_2 \rightarrow$ Days \downarrow	3.8	4	4.2	4.4	4.6
30	0.910275	0.910289	0.910302	0.910314	0.910324
60	0.910275	0.910289	0.910302	0.910314	0.910324
90	0.910275	0.910289	0.910302	0.910314	0.910324
120	0.910275	0.910289	0.910302	0.910314	0.910324
150	0.910275	0.910289	0.910302	0.910314	0.910324
180	0.910275	0.910289	0.910302	0.910314	0.910324
210	0.910275	0.910289	0.910302	0.910314	0.910324
240	0.910275	0.910289	0.910302	0.910314	0.910324
270	0.910275	0.910289	0.910302	0.910314	0.910324
300	0.910275	0.910289	0.910302	0.910314	0.910324
330	0.910275	0.910289	0.910302	0.910314	0.910324
360	0.910275	0.910289	0.910302	0.910314	0.910324
MTTF	291.2879	291.2966	291.3003	291.3037	291.3068

(x) Effect of repair rate of Destoner Machine (β_3) on reliability of the system:

Result of repair rate of sub-system, Destoner Machine on the reliability of the system with varying its values as $\beta_3 = 48, 48.2, 48.4, 48.6, 48.8$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. Table 2.1(j) shows that the result of destoner machine (β_3) on the reliability of the system. Reliability of the system increases with estimate 0.0001% but the reliability remains same with the increments the time from 30 to 3600

hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(j): EFFECT OF FAILURE (β_3) DESTONER MACHINE ON RELIABILITY OF THE SYSTEM

$\beta_3 \rightarrow$ Days \downarrow	48	48.2	48.4	48.6	48.8
30	0.910275	0.910275	0.910275	0.910276	0.910276
60	0.910275	0.910275	0.910275	0.910276	0.910276
90	0.910275	0.910275	0.910275	0.910276	0.910276
120	0.910275	0.910275	0.910275	0.910276	0.910276
150	0.910275	0.910275	0.910275	0.910276	0.910276
180	0.910275	0.910275	0.910275	0.910276	0.910276
210	0.910275	0.910275	0.910275	0.910276	0.910276
240	0.910275	0.910275	0.910275	0.910276	0.910276
270	0.910275	0.910275	0.910275	0.910276	0.910276
300	0.910275	0.910275	0.910275	0.910276	0.910276
330	0.910275	0.910275	0.910275	0.910276	0.910276
360	0.910275	0.910275	0.910275	0.910276	0.910276
MTTF	291.2879	291.2925	291.2926	291.2927	291.2927

(xi) Effect of Repair rate of Whitener Machine (β_4) on reliability of the system: Result of repair rate of sub-system, Whitener Machine on the reliability of the system with varying its values as $\beta_4 = 1.0, 1.2, 1.4, 1.6, 1.8$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_5 = 12, \beta_6 = 12, \beta_7 =$

2.1238. Table 2.1(k) shows that the result of whitener machine (β_4) on the reliability of the system. Reliability of the system increases with estimate 0.109% but the reliability remains same with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(k): EFFECT OF REPAIR RATE (β_4) WHITENER MACHINE ON RELIABILITY OF THE SYSTEM

$\beta_4 \rightarrow$ Days↓	1.0	1.2	1.4	1.6	1.8
30	0.910275	0.910648	0.910915	0.911115	0.911270
60	0.910275	0.910648	0.910915	0.911115	0.911270
90	0.910275	0.910648	0.910915	0.911115	0.911270
120	0.910275	0.910648	0.910915	0.911115	0.911270
150	0.910275	0.910648	0.910915	0.911115	0.911270
180	0.910275	0.910648	0.910915	0.911115	0.911270
210	0.910275	0.910648	0.910915	0.911115	0.911270
240	0.910275	0.910648	0.910915	0.911115	0.911270
270	0.910275	0.910648	0.910915	0.911115	0.911270
300	0.910275	0.910648	0.910915	0.911115	0.911270
330	0.910275	0.910648	0.910915	0.911115	0.911270
360	0.910275	0.910648	0.910915	0.911115	0.911270
MTTF	291.2879	291.4118	291.4972	291.5612	291.5612

(xii) Effect of Repair rate of Length Grader (β_5) on reliability of the system:

Results of repair rate of sub-system, namely, Length Grader on the reliability of the

system with varying its values as $\beta_5 = 12, 12.2, 12.4, 12.6, 12.8$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_6 = 12, \beta_7 = 2.1238$. Table 2.1(i) shows the that result of length garder (β_5) on the reliability of the system. Reliability of the system increases with estimate 0.002% but the reliability remains same with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(i): EFFECT OF REPAIR RATE (β_5) LENGTH GRADER ON RELIABILITY OF THE SYSTEM

$\beta_5 \rightarrow$ Days↓	12	12.2	12.4	12.6	12.8
30	0.910275	0.910281	0.910287	0.910293	0.910298
60	0.910275	0.910281	0.910287	0.910293	0.910298
90	0.910275	0.910281	0.910287	0.910293	0.910298
120	0.910275	0.910281	0.910287	0.910293	0.910298
150	0.910275	0.910281	0.910287	0.910293	0.910298
180	0.910275	0.910281	0.910287	0.910293	0.910298
210	0.910275	0.910281	0.910287	0.910293	0.910298
240	0.910275	0.910281	0.910287	0.910293	0.910298
270	0.910275	0.910281	0.910287	0.910293	0.910298
300	0.910275	0.910281	0.910287	0.910293	0.910298
330	0.910275	0.910281	0.910287	0.910293	0.910298
360	0.910275	0.910281	0.910287	0.910293	0.910298
MTTF	291.2879	291.2944	291.2963	291.2982	291.2999

(xiii) Effect of Repair rate of Sortex Machine (β_6) on reliability of the system:

Now we calculate the reliability of the system with the varying repair rate of Sortex machine. We have taken $\beta_6 = 12.0, 12.2, 12.4, 12.6, 12.8$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_7 = 2.1238$. Table 2.1(m) shows that the result of sortex machine (β_6) on the reliability of the system. Reliability of the system increases with estimate 0.001% but the reliability remains same with the increments the time from 30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(m): EFFECT OF REPAIR RATE (β_6) SORTEX MACHINE ON RELIABILITY OF THE SYSTEM

$\beta_6 \rightarrow$ Days \downarrow	12.0	12.2	12.4	12.6	12.8
30	0.910275	0.910278	0.910281	0.910284	0.910287
60	0.910275	0.910278	0.910281	0.910284	0.910287
90	0.910275	0.910278	0.910281	0.910284	0.910287
120	0.910275	0.910278	0.910281	0.910284	0.910287
150	0.910275	0.910278	0.910281	0.910284	0.910287
180	0.910275	0.910278	0.910281	0.910284	0.910287
210	0.910275	0.910278	0.910281	0.910284	0.910287
240	0.910275	0.910278	0.910281	0.910284	0.910287
270	0.910275	0.910278	0.910281	0.910284	0.910287
300	0.910275	0.910278	0.910281	0.910284	0.910287
330	0.910275	0.910278	0.910281	0.910284	0.910287
360	0.910275	0.910278	0.910281	0.910284	0.910287
MTTF	291.2879	291.2934	291.2944	291.2953	291.2962

(xiv) Effect of repair rate of Packing Machine (β_7) on reliability of the system:

Again we calculate the reliability of the system with consider the hazard rate (failure rates) and repair rates. We have taken $\beta_7 = 2.1238, 2.3238, 2.5238, 2.7238, 2.9238$ and other parameters are taken as: $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12$. Table 2.1(n) shows that the result of packing machine (β_7) on the reliability of the system. Reliability of the system increases with estimate 2.4% but the reliability remains same with the increments the time from

30 to 3600 hours. Although reliability decreases for a short period initially and then remains the same throughout the year.

Table 2.1(n): EFFECT OF REPAIR RATE (β_7) PACKING MACHINE ON RELIABILITY OF THE SYSTEM

$\beta_7 \rightarrow$ Days \downarrow	2.1238	2.3238	2.5238	2.7238	2.9238
30	0.910275	0.917041	0.922812	0.927794	0.935959
60	0.910275	0.917041	0.922812	0.927794	0.935959
90	0.910275	0.917041	0.922812	0.927794	0.935959
120	0.910275	0.917041	0.922812	0.927794	0.935959
150	0.910275	0.917041	0.922812	0.927794	0.935959
180	0.910275	0.917041	0.922812	0.927794	0.935959
210	0.910275	0.917041	0.922812	0.927794	0.935959
240	0.910275	0.917041	0.922812	0.927794	0.935959
270	0.910275	0.917041	0.922812	0.927794	0.935959
300	0.910275	0.917041	0.922812	0.927794	0.935959
330	0.910275	0.917041	0.922812	0.927794	0.935959
360	0.910275	0.917041	0.922812	0.927794	0.935959
MTTF	291.2879	293.4575	295.3046	296.8988	298.2889

2.5 Analysis of Results

The tables 2.1(a) to 2.1(n) show that the sub-system G i.e. packing machine affects the reliability more than other sub-systems. As a result management need to be careful of this sub-system.

The values of reliability is not much clear in table as it remains the same but there is a substantial change which is cleared through the graph. This behaviour is only for a short duration.

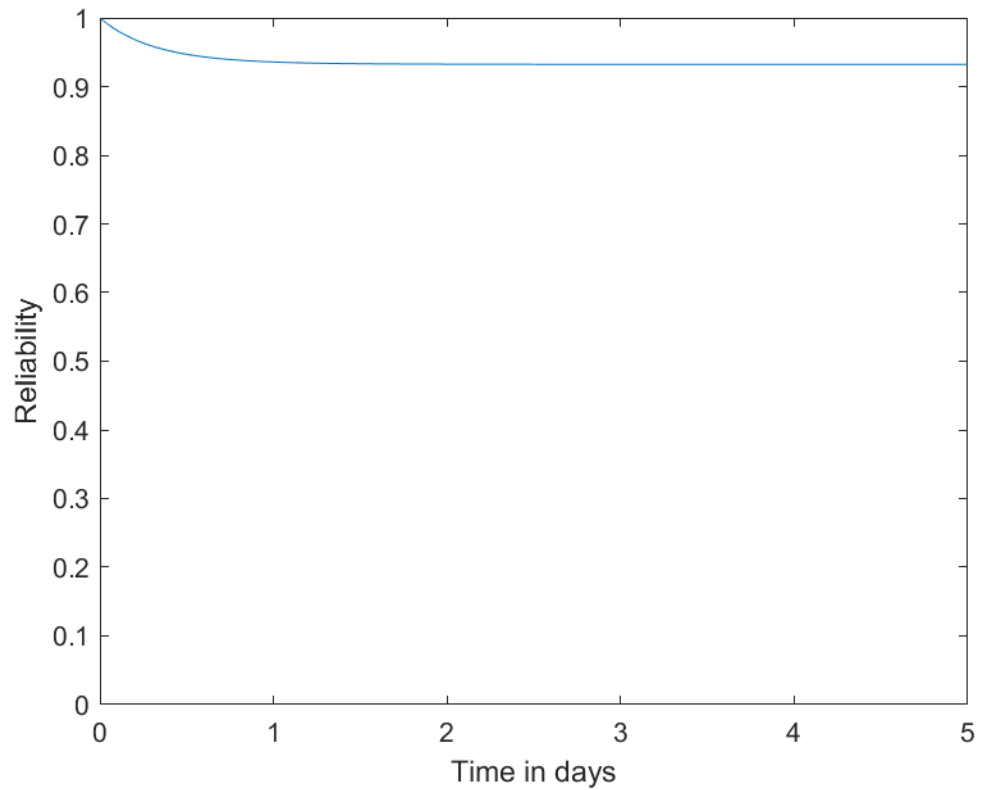


Fig. 2.3: Variation of reliability for 5 days only.

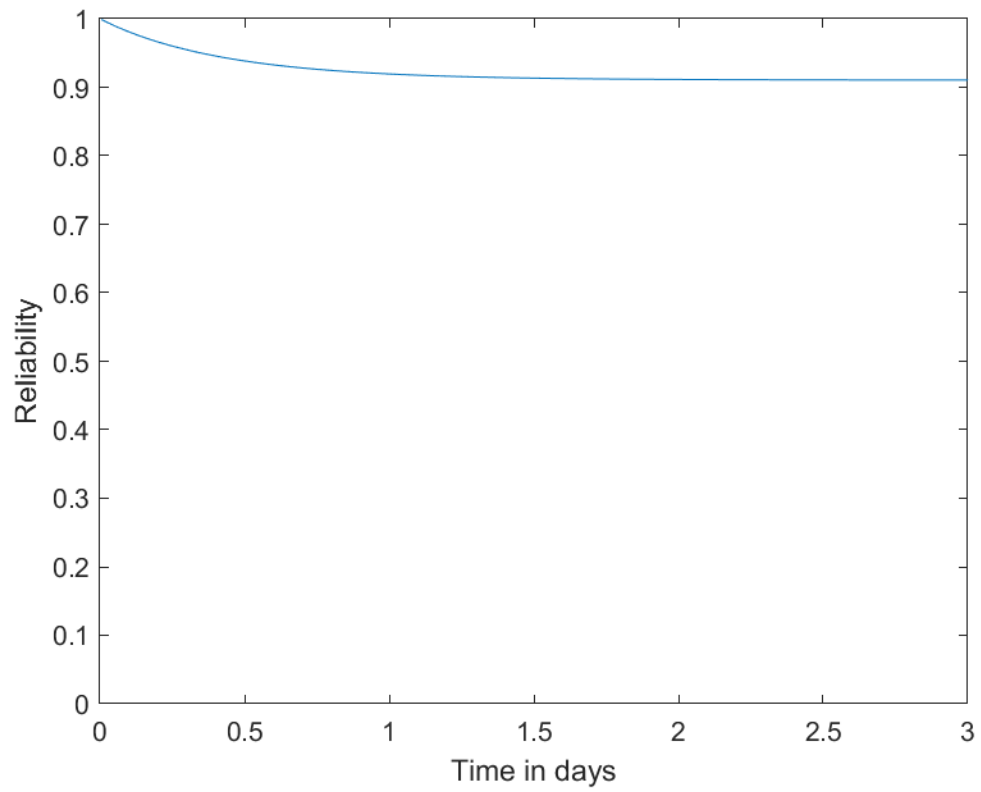


Fig. 2.4: Variation of reliability for 3 days only

CHAPTER 3

AVAILIBILITY ANALYSIS OF RICE MANUFACTURING PLANT

In this chapter, we discuss the availability of rice manufacturing plant. This chapter is organised as follows:

Section 3.1 presents Mathematical formula for the availability analysis situation of the mathematical problem or further numerical analysis are discussed in section 3.2. Certain conclusions drawn from the results are discussed in Section 3.3. Finally, industrial significance of the results and scope of further research have been presented in Section 3.4. The administrators are generally involved in long run availability of the system. So, steady state probabilities of the system are required for availability which are reached by taking $\frac{d}{dt} \rightarrow 0$ as $t \rightarrow \infty$.

3.1 Mathematical Formulation

The differential equations (2.1 – 2.9) have been reduced to the following system of the linear system of equation. For finding the steady state probability of the sub-system.

$$\lambda_1 P_0(t) = \beta_1 P_1(t) + \beta_2 P_2(t) + \beta_3 P_3(t) + \beta_4 P_4(t) + \beta_5 P_5(t) + \beta_6 P_6(t) + \beta_7 P_7(t) \quad (3.1)$$

$$\beta_1 P_1(t) = \alpha_1 P_0(t) \quad (3.2)$$

$$\beta_2 P_2(t) = \alpha_2 P_0(t) \quad (3.3)$$

$$\beta_3 P_3(t) = \alpha_3 P_0(t) \quad (3.4)$$

$$\beta_4 P_4(t) = \alpha_4 P_0(t) \quad (3.5)$$

$$\beta_5 P_5(t) = \alpha_5 P_0(t) \quad (3.6)$$

$$\beta_6 P_6(t) = \alpha_6 P_0(t) \quad (3.7)$$

$$\beta_7 P_7(t) = \alpha_7 P_0(t) \quad (3.8)$$

Where,

$$\lambda_1 = \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 + \alpha_6 + \alpha_7$$

with the initial conditions $P_1(0) = 1$ and 0 otherwise. (3.9)

The normalizing condition is given as:

$$\sum_{i=0}^7 P_i(t) = 1 \quad (3.10)$$

The system of the system of linear equations (3.1 – 3.10) gives the steady state probabilities of the various sub-system. Hence using these results, Long run availability of the system can be obtained as

$$A(\infty) = P_0(t) \quad (3.11)$$

3.2 Numerical Analysis

In order to solve system of linear equation (3.1 - 3.10), we have used Gauss Elimination method. Since this is a homogenous system of linear equation and provides a trivial solution, we have replaced any one condition within (3.1) to (3.9) by the condition (3.11) to make it non-homogenous system. As several combines of failure rates and repair rates, we have calculated the system and abridged the conclusion as follows.

(a) Effect of hazards rates and repair rates of storage bin (α_1, β_1) on availability of the system:

Now we are taking the hazard rates and repair rates of sub-systems. All the hazard rates and repair rates other than α_1 and β_1 are constants and vary the hazard rates and repair rates of $\alpha_1 = 0.005, 0.007, 0.009, 0.0011, 0.0013$ and $\beta_1 = 8, 8.2, 8.4,$

8.6, 8.8 and taking other values as $\alpha_2 = 0.0013$, $\alpha_3 = 0.0027$, $\alpha_4 = 0.0027$, $\alpha_5 = 0.0054$, $\alpha_6 = 0.0027$, $\alpha_7 = 0.2$, $\beta_2 = 3.8$, $\beta_3 = 48$, $\beta_4 = 1$, $\beta_5 = 12$, $\beta_6 = 12$, $\beta_7 = 2.1238$. The table 3.1(a) shows that increment in hazard rate (failure rate) (α_1) reduces availability by 0.09% and repair rate (β_1) increases the availability by 0.005%.

Table 3.1(a): EFFECT OF HAZARD RATES AND REPAIR RATES OF STORAGE BIN (α_1, β_1) ON AVAILABILITY OF THE SYSTEM

$\alpha_1 \rightarrow$ $\beta_1 \downarrow$	0.005	0.007	0.009	0.011	0.013
8	0.91027	0.910668	0.909861	0.909654	0.909447
8.2	0.910288	0.910036	0.909884	0.909682	0.909480
8.4	0.910300	0.910102	0.909905	0.909708	0.909511
8.6	0.910311	0.910118	0.909926	0.909733	0.909541
8.8.	0.910322	0.910134	0.909946	0.909757	0.909569

(b) Effect of hazards rates and repair rates of Cleaner machine (α_2, β_2) on availability of the system:

Now we are taking the hazard rates and repair rates of sub-systems. All the hazard rates and repair rates other than α_2 and β_2 are constants and vary the hazard rates and repair rates of $\alpha_2 = 0.0013, 0.0033, 0.0053, 0.0073, 0.0093$ and $\beta_2 = 3.8, 4, 4.2, 4.4, 4.6$ and taking other values as $\alpha_1 = 0.005$, $\alpha_3 = 0.0027$, $\alpha_4 = 0.0027$, $\alpha_5 = 0.0054$, $\alpha_6 = 0.0027$, $\alpha_7 = 0.2$, $\beta_1 = 8$, $\beta_3 = 48$, $\beta_4 = 1$, $\beta_5 = 12$, $\beta_6 = 12$, $\beta_7 = 2.1238$. The table 3.1(b) shows that increment in hazard rate (failure rate) (α_2) reduces availability by 0.19% and repair rate (β_2) increases the availability by 0.005%.

Table 3.1(b): EFFECT OF HAZARD RATES AND REPAIR RATES OF CLEANER MACHINE (α_2, β_2) ON AVAILABILITY OF THE SYSTEM

$\alpha_2 \rightarrow$ $\beta_2 \downarrow$	0.0013	0.0033	0.0053	0.0073	0.0093
3.8	0.91027	0.909839	0.909404	0.908969	0.908534
4	0.910289	0.909875	0.909461	0.909048	0.908635
4.2	0.910302	0.909908	0.909513	0.909120	0.908726
4.4	0.910314	0.909937	0.909561	0.909185	0.908809
4.6	0.910324	0.909964	0.909604	0.909245	0.908885

(c) Effect of hazards rate (failure rates) of (α_3, β_3) Destoner Machine on availability of the system:

Now we are taking the hazard rates and repair rates of sub-systems. All the hazard rates and repair rates other than α_3 and β_3 are constants and vary the hazard rates and repair rates of $\alpha_3 = 0.0027, 0.0047, 0.0067, 0.0087, 0.0107$ and $\beta_3 = 48, 48.2, 48.4, 48.6, 48.8$ and taking other values as $\alpha_2 = 0.005, \alpha_2 = 0.0013, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. The table 3.1(c) shows that increment in hazard rate (failure rate) (α_3) reduces availability by 0.014% and repair rate (β_3) increases the availability by 0.0006%.

Table 3.1(c): EFFECT OF HAZARD RATES AND REPAIR RATES OF DESTONER MACHINE (α_3, β_3) ON AVAILABILITY OF THE SYSTEM

$\alpha_3 \rightarrow$ $\beta_3 \downarrow$	0.0027	0.0047	0.0067	0.0087	0.0107
48	0.91027	0.910240	0.910206	0.910171	0.910137
48.2	0.910275	0.910241	0.910206	0.910172	0.910138
48.4	0.910275	0.910241	0.910207	0.910173	0.910138
48.6	0.910276	0.910241	0.910207	0.910173	0.910139
48.8	0.910276	0.910242	0.910208	0.910174	0.910140

(d) Effect of hazards rates (failure rates) of Whitener Machine (α_4) and Packing Machine (α_7) on availability of the system:

Now we are taking the hazard rates and repair rates of sub-systems. All the hazard rates and repair rates other than α_4 and α_7 are constants and vary the hazard rates and repair rates of $\alpha_4 = 0.0027, 0.0047, 0.0067, 0.0087, 0.0107$ and $\alpha_7 = 0.2, 0.4, 0.6, 0.8, 0.10$ and taking other values as $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12, \beta_7 = 2.1238$. The table 3.1(d) shows that increment in hazard rate (failure rate) (α_4) reduces availability by 0.722% and failure rate (α_7) increases the availability by 4.47%.

Table 3.1(d): EFFECT OF HAZARD RATES (FAILURE RATES) OF WHITENER MACHINE (α_2) AND PACKING MACHINE (α_7) ON AVAILABILITY OF THE SYSTEM

$\alpha_4 \rightarrow$ $\alpha_7 \downarrow$	0.0027	0.0047	0.0067	0.0087	0.0107
0.2	0.910275	0.908621	0.906973	0.905330	0.903694
0.4	0.838406	0.837002	0.835603	0.834209	0.832820
0.6	0.777055	0.775849	0.774647	0.770949	0.772254
0.8	0.724070	0.723023	0.721979	0.720938	0.719900
0.10	0.951037	0.949232	0.947433	0.945641	0.943856

(e) Effect of hazards rates and repair rates of Length Grader (α_5) and Packing Machine(β_7) on availability of the system:

Now we are taking the hazard rates and repair rates of sub-systems. All the hazard rates and repair rates other than α_5 and β_7 are constants and vary the hazard rates and repair rates of $\alpha_5 = 0.0054, 0.0074, 0.0094, 0.0114, 0.0134$ and $\beta_7 = 2.1238, 2.3238, 2.5238, 2.7238, 2.9238$ and taking other values as $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12$. The table 3.1(e) shows that increment in hazard rate (failure rate) (α_5) reduces availability by 0.06% and repair rate (β_7) increases the availability by 2.4%.

Table 3.1(e): EFFECT OF HAZARD RATES AND REPAIR RATES OF LENGTH GRADER (α_5) AND PACKING MACHINE (β_7) ON AVAILABILITY OF THE SYSTEM

$\alpha_5 \rightarrow$ $\beta_7 \downarrow$	0.0054	0.0074	0.0094	0.0114	0.0134
2.1238	0.910275	0.910137	0.909999	0.909861	0.909723
2.3238	0.917041	0.916900	0.916760	0.916620	0.916480
2.5238	0.922812	0.922670	0.922529	0.922387	0.922245
2.7238	0.927794	0.927651	0.927507	0.927364	0.927221
2.9238	0.932138	0.931993	0.931848	0.931704	0.931559

(f) Effect of repair rates of Cleaner Machine (β_2) and Sortex Machine(β_6) on availability of the system:

Now we are taking the hazard rates and repair rates of sub-systems. All the hazard rates and repair rates other than β_2 and β_6 are constants and vary the failure rates and repair rates of $\beta_2 = 3.8, 4, 4.2, 4.4, 4.6$ and $\beta_6 = 12, 12.2, 12.4, 12.6, 12.8$ and taking other values as $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \alpha_7 = 0.2, \beta_1 = 8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_7 = 2.1238$. The table 3.1(f) shows that increment in repair rate (β_2) reduces availability by 0.005% and repair rate (β_6) increases the availability by 0.001%.

Table 3.1(f): EFFECT OF REPAIR RATES OF CLEANER MACHINE AND SORTEX MACHINE (β_2, β_6) ON AVAILABILITY OF THE SYSTEM

$\beta_2 \rightarrow$ $\beta_6 \downarrow$	3.8	4	4.2	4.4	4.6
12	0.910275	0.910289	0.910302	0.910314	0.910324
12.2	0.910278	0.910292	0.910305	0.910317	0.910327
12.4	0.910281	0.910295	0.910308	0.910320	0.910330
12.6	0.910284	0.910298	0.910311	0.910322	0.910333
12.8	0.910287	0.910301	0.910314	0.910325	0.910336

(g) Effect of hazards rate (failure rates) repair rates of Packing Machine (α_7, β_7) on availability of the system:

Now we are taking the hazard rates and repair rates of sub-systems. All the hazard rates and repair rates other than α_7 and β_7 are constants and vary the hazard rates and repair rates of $\alpha_7 = 0.2, 0.4, 0.6, 0.8, 0.10$ and $\beta_7 = 2.1238, 2.3238, 2.5238, 2.7238, 2.9238$ and taking other values as $\alpha_1 = 0.005, \alpha_2 = 0.0013, \alpha_3 = 0.0027, \alpha_4 = 0.0027, \alpha_5 = 0.0054, \alpha_6 = 0.0027, \beta_1 = 8, \beta_2 = 3.8, \beta_3 = 48, \beta_4 = 1, \beta_5 = 12, \beta_6 = 12$. The table 3.1(g) shows that increment in hazard rate (failure rate) (α_7) reduces availability by 4.47% and repair rate (β_7) increases the availability by 2.64%.

Table 3.1(g): EFFECT OF REPAIR RATES OF PACKING MACHINE (α_7, β_7) ON AVAILABILITY OF THE SYSTEM

$\alpha_7 \rightarrow$ $\beta_7 \downarrow$	0.2	0.4	0.6	0.8	0.10
2.1238	0.910275	0.838406	0.777055	0.724070	0.951037
2.3238	0.917041	0.849957	0.792019	0.741476	0.954717
2.5238	0.922812	0.859927	0.805065	0.756784	0.957835
2.7238	0.927794	0.868620	0.816541	0.770353	0.960512
2.9238	0.932138	0.876266	0.826712	0.782464	0.962834

Further, for validation of the computed results of the system (3.1 – 3.10), we also solved them analytically. The probabilities can be obtained recursively from (3.1 – 3.10) as follows :

$$P_1(t) = \frac{\alpha_1}{\beta_1} P_0(t) \quad (3.12)$$

$$P_2(t) = \frac{\alpha_2}{\beta_2} P_0(t) \quad (3.13)$$

$$P_3(t) = \frac{\alpha_3}{\beta_3} P_0(t) \quad (3.14)$$

$$P_4(t) = \frac{\alpha_4}{\beta_4} P_0(t) \quad (3.15)$$

$$P_5(t) = \frac{\alpha_5}{\beta_5} P_0(t) \quad (3.16)$$

$$P_6(t) = \frac{\alpha_6}{\beta_6} P_0(t) \quad (3.17)$$

$$P_7(t) = \frac{\alpha_7}{\beta_7} P_0(t) \quad (3.18)$$

Substituting the equation (3.12 – 3.18) in equation (3.10), we get

$$P_0 = \left[1 + \frac{\alpha_1}{\beta_1} + \frac{\alpha_2}{\beta_2} + \frac{\alpha_3}{\beta_3} + \frac{\alpha_4}{\beta_4} + \frac{\alpha_5}{\beta_5} + \frac{\alpha_6}{\beta_6} + \frac{\alpha_7}{\beta_7} \right]^{-1} \quad (3.12)$$

Once this P_0 is known the probability of other state can also be determine

Long run availability of the system can be measured as

$$A(\infty) = P_0(t)$$

By using these expressions, we have computed long run availability for the same data taken in table 3.1(a). The results for $A(\infty)$ are shown in table 3.1(h).

Table 3.1(h): EFFECT OF HAZARD RATES AND REPAIR RATES OF STORAGE BIN (α_1, β_1) ON AVAILABILITY OF THE SYSTEM

$\alpha_1 \rightarrow$ $\beta_1 \downarrow$	0.005	0.007	0.009	0.011	0.013
8	0.910279	0.910072	0.909865	0.909658	0.909452
8.2	0.910292	0.910090	0.909888	0.909686	0.909484
8.4	0.910304	0.910107	0.909910	0.909713	0.909516
8.6	0.910316	0.910123	0.909930	0.909738	0.909545
8.8.	0.910326	0.910138	0.909950	0.909762	0.909574

On comparing the results of tables 3.1(a) and 3.1(h), we conclude that they are agreeing upto four decimal place. This validation our results obtained for the availability of rice manufacturing plant.

3.3 CONCLUSION

From tables 3.1(a) to 3.1(g) we conclude that G affects the availability more than any another system. So, management should take care to Packing Machine. It is a very sensitive system.

3.4 Limitations of research work

There are some limitations on research work as follows :

(i) It was an extremely problematic task to gather real information from the industry. KRBL Limited (INDIA) provided some data for the rice manufacturing machines which, therefore, are used to find failure / repair rates. Due to the lack of availability of certain information, some measures had to be taken.

(ii) The model discussed in this thesis may not meet all the needs of the industry, so it may need more changes.

(iii) To determine the different proportions of the effectiveness of the system, we have tried to understand the disposition of the differential condition using the Runge kutta method. This technique is simple when the arrangement of the differential equations is small, however, it becomes complex for the enormous disposition of the differential equation.

(iv) We have not investigated the effect of failures and repair rates of other subsystems due to the inadequate information we receive from the industry.

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