PREDICTION OF RELIABILITY CHARACTERISTICS OF THRESHER PLANT BASIS ON GENERAL AND COPULA DISTRIBUTION

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Abstract

In the agriculture field industry, farming tools play an important role. Any type of machinery's performance is influenced by factors including dependability, accessibility, and operating conditions. Different types of modern machinery are being used in today's modern world, so the farming system has become very easy. Thresher plants are essential equipment in the agriculture field industry, and these plants have many uses. A transition diagram for the system is used to develop a mathematical model of the thresher plant. Partial differential equations are created associated with the help of a transition diagram and solved using Laplace transforms and the supplementary variables approach to assessing the system's reliability. The copula approach was used to design the experiment, and the same methodology was used to assess the outcomes. The main aim of the present article is to evaluate the reliability factors, Profit, and sensitive analysis of a threshers plant. It is also possible to compute the dependability factor with the aid of general distributions and compare it to that copula distribution.

Keywords: Reliability, MTTF, sensitivity analysis, copula and general distribution, availability, profit.

1. Introduction

Especially for emerging nations, agriculture is a crucial component of the global economy. India is an agricultural field country. Here many people do farming and use different tools of farming machinery. In this field, the thresher farmer tool plays a very important role in farming. Different kinds of threshers have been used in today's machinery and the modern technological world. That's why now farming has become very easy for the farmer. It is necessary for good farming that the farming tools should work well. Basically, there are several uses for a thresher plant; it is used for cutting grass and threshing grain. This plant is mainly used for threshing grain. It is necessary for good farming results that all its equipment or its subsystem should work well. For this plant subsystem to properly, without fail, they have to be more reliable. Reliability theory's primary goal is to evaluate measurement mistakes and offer suggestions on improving the tests so that errors are reduced, maximizing profit, availability, and reliability. System reliability plays a very important role in working with any system or its component. When the system is failed, then repair with a repair facility, after repair system how is available. Analysis of a system's or component's ability to function under particular conditions is known as reliability. In essence, it is a probability that a system will function correctly or not at a given moment.

Our civilization is becoming more complicated, and with that complexity come more pressing reliability issues that need to be resolved, and reliability issues are one of them. The area of reliability engineering is now receiving significant attention from many researchers and experts. Here is a brief description of these researchers and their research.

Singh, P.c and Pande [1] their model is based on the Chapman-Kolmogorov equation and uses five subsystems of the crystallizing system in the series form to analyze the availability and dependability of the system in sugar factories. Dhillon and B. S. [2] the essay examines the dependability and availability of a two-unit parallel system with warm standby and common-cause failures. Veera Raghavan, Trivedi, and K. S [3] Combinatorial models have been used to simulate the availability and dependability of complex systems without incurring the cost associated with massive Markov models. Perman and other [4] analyses using the power plant that When the transition probabilities are compared, it can be shown that the likelihood of the system refitting converges to its limiting value more rapidly than it does in the Markov model. Marquez and other authors [5] to calculate the reliability and availability of a complicated cogeneration plant employ the Monte Carlo and continuous time Monte Carlo simulation technique; in that paper, a case study for cogeneration plants is also presented. Bansal S [6] compares two independent repairable subsystems based on their availability to assess the complex system using the supplemental variable technique. Shikha Bansal and Sohan tyagi [7] calculated the reliability of a screw plant using the Boolean algebra approach and the orthogonal matrix method. Kumar, Modgil and others [8] use particle swarm optimization and genetic algorithm for availability analysis of ethanol manufacturing system; they analyze the result that PSO gives more accurate availability compared to genetic algorithm. Vinod, Amit, and others [9] introduce a new hybrid bacterial foraging algorithm and compare BFO and PSO optimization algorithms for optimizing the performance and availability of paint manufacturing systems. Yusuf, I., Ismai [10] analyze the reliability characteristic of the multi-computer systems using Laplace transforms and supplementary variable techniques. Saini, M., Raghav [11] using genetic and particle swarm optimization increase the urea decomposition system's dependability and availability. Tyagi and other researchers [12], using the Markov birth-death process, create a mathematical model of a leaf spring production facility and optimize the availability of a plant with regard to time utilizing C programming techniques. Sarwar and other researchers [13] determined sugar-producing plants' maintainability, availability, and dependability. Dionysiou, Bolbo, and other researchers [14] identify the best-fit distribution for a plant's failure and repair rates using various statistical features like skewness, kurtosis, and others. On a cruise ship, the lubricating oil system was examined in order to determine how to increase its dependability, availability, and safety. Bansal, Tyagi, and Verma [15] analyse the deviation of availability for screw plants with the help of the Markov birth-death Process and Matlab tool. Godara and Bansal [16] evaluate the reliability and availability of steam turbine generator plants using the boolean function technique and neural network approach. Tyagi and Bansal [17] optimize the performance of the Wastewater Treatment Process plant using the Runge-Kutta method. Chaudhary and Bansal [18] evaluate the reliability charismatic of the Hydro-Electric Power Station plant using Hydro-Electric Power Station.

There has not been a thorough analysis and sensitivity analysis of the availability of thresher plant subsystems. However, a few articles are accessible on the economics of production and maintenance management in the thresher plant.

Our primary goal is to study the system's availability and reliability utilizing alternative distributions; utilizing them maximises the thresher plant system availability. In this research, we analyze three possible states of the system: good, reduce, and failed. In this article, we also discuss the profit and sensitivity analysis of the system; however, we maximise the plant's profit and how to vary the sensitivity analysis of the thresher plant.

2. Notation

t	Time frame with a time variable
s	Expression of a Laplace transformation
τ_i	Subsystem i failure frequency.
ξ_i	Subsystem repair with copula repair facility.
$\omega_i(x)$	Subsystem repair with general repair facility
$P_i(x,t)$	The system state probability in i^{th} state.
$P_i(x,t)$	Laplace transform of i^{th} state probability.
$S_\omega(x)$	Standard general distribution.
$C_\theta(\xi_(x))$	Standard Copula distribution.
$E_p(t)$	Predicted profit throughout the time period [0,t].
M_1, M_2	Per unit of time, revenue and service costs.

3. Assumption

The following assumption is taken through the model description.

- Initially, the whole system is completely operable or working state.
- Good, reduced, and failed states are the three possible system states.
- System is repairable after complete failed and partial failed state, i.e. repair facility available in the system.
- After repair system works properly in a good state, and there are two types of repair facilities in the system: general repair and copula repair facility.
- When systems partially fail, follow the general standard distribution.
- When systems are completely failed, then follow Copula standard distribution.

4. Description of The System

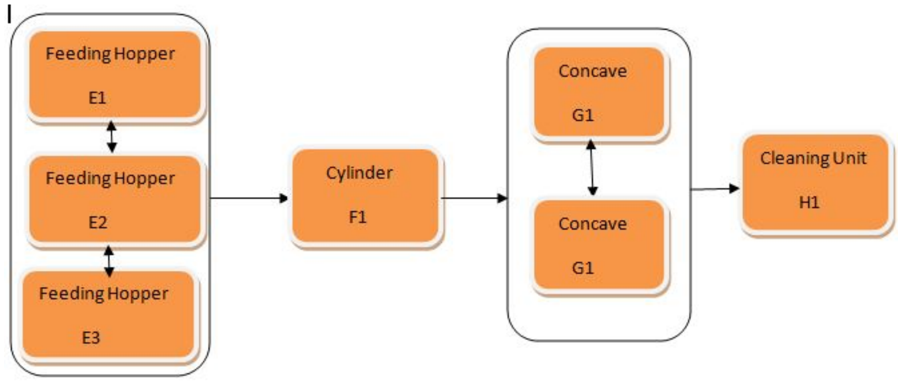

Figure 1: *Block diagram for Thresher Plant*

The machine's availability affects how well it performs in agricultural applications, the equipment's environment, its procedure, and how effectively it is maintained. The block diagram of the thresher plant is shown in Figure 1. There are four subsystems in the plant. In this part, we give a brief description of the thresher plant. It involves removing grain from the plant by rupturing, trampling, and striking. It is the most crucial element of agricultural automation.

1. $\textit{FeedingHopper}$ **:** — It is placed on the top of the threshing cylinder. Grain is first entered through the hopper. To deliver uniform (equally) sized grains to the drum, this machine uses a revolving star wheel mechanism between the hopper and the threshing drum.

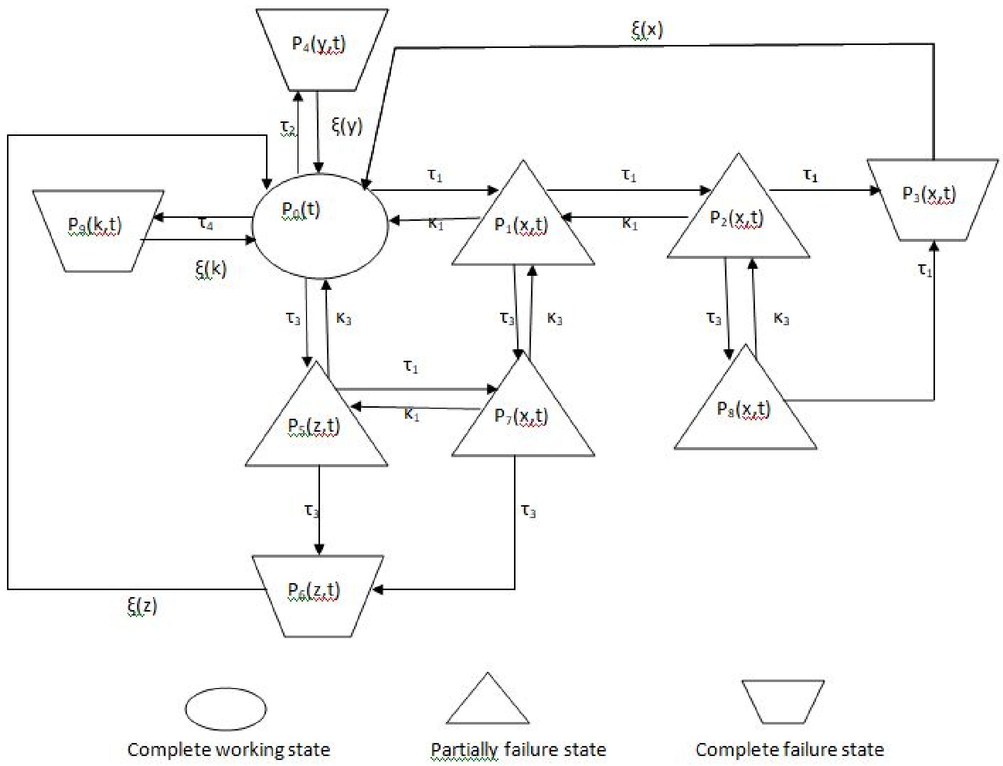

Figure 2: *Transition diagram for Thresher Plant*

2. ***Cylinder* :** —There are different types of cylinders used in the thresher plant, e.g., wire loop type, spike tooth type, and rasp bar type cylinder. These primarily used cylinders in the threshing plant. Grain enters in the moving direction of the cylinder.

3. ***Concave* :** —It is a curved piece of iron and steel situated next to the threshing cylinder. It removes grain from the straw and separates grain from the harvest. Only grain and a limited quantity of chaff are allowed to pass through it, holding the feed crop inside the threshing chamber. According to the crop size, the distance between the concave and the cylinder can be adjusted.

4. ***CleaningUnit* :** — With the use of blowers and aspirators, the grain is separated from the chalk.

5. State Description

- S_0 **:** —In the initial state, Units E_1, F_1, G_1, and H_1 are operational. Units E_2, E_3, and G_2 are currently in standby mode.
- S_1 **:** — In this state , the unit E_1 failed and under repair. And the elapsed repair time is (x,t). While the unit E_2, F_1, G_1 and H_1, are on operation and the units E_3 and G_2 are on standby.
- S_2 **:** — Units E_1 and E_2 failed and were being repaired in this state. The repair time that has already passed is (x,t). While the units E_2,F_1,G_1,H_1, and E_3 are in operation and on standby, respectively.
- S_3 **:** — In both the units E_1 and G_1, there has been a failure. The units E_2 and E_3 are on standby while E_2, F_1, G_2, and H_1 are in operation.
- S_4 **:** —In this instance, the subsystem 1 units E_1 and E_2 are involved. Additionally, G_1 from subsystem three has failed and is being repaired. When performing operations, the unit E_3, from subsystem 1, F_1, from subsystem 2, G_2, from subsystem 3, and H_1 from subsystem 4.

- **S_5 :** — Due to subsystem 2's failure, state S_5 is a fully failed state.
- **S_6 :** — Due to subsystem 1's failure, state S_6 is a fully failed state.
- **S_7 :** — Due to subsystem 3 failure, state S_5 is a fully failed state.
- **S_8 :** — Due to subsystem 4 failure, state S_5 is a fully failed state.

6. Formulation and Solution of The Mathematical Model

The mathematical model solves the following collection of distinct differential equations. These differential equations are derived with the help of a transition diagram. Hence the mathematical model is as follows.

$$[\frac{\partial}{\partial t} + \tau_1 + \tau_2 + \tau_3 + \tau_4]P_0 = \int_0^\infty \kappa_1 P_1(y,t) + \int_0^\infty \xi(x) P_4(x,t) + \int_0^\infty \kappa_3 P_5(z,t) + \int_0^\infty \xi(k) P_9(y,t) + \int_0^\infty \xi(x) P_3(x,t) + \int_0^\infty \xi(z) P_5(z,t) \tag{1}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial x} + \tau_1 + \tau_3 + \kappa_1)P_1(x,t) = 0 \tag{2}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial x} + \tau_1 + \tau_3 + \kappa_1)P_2(x,t) = 0 \tag{3}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial y} + \xi(x))P_3(x,t) = 0 \tag{4}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial y} + \xi(y))P_4(y,t) = 0 \tag{5}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial z} + \tau_1 + \tau_3 + \kappa_3)P_5(x,t) = 0 \tag{6}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial z} + \xi(z))P_6(z,t) = 0 \tag{7}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial x} + \tau_3 + 2\kappa_1)P_7(x,t) = 0 \tag{8}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial x} + \tau_1 + \kappa_3)P_8(x,t) = 0 \tag{9}$$

$$(\frac{\partial}{\partial t} + \frac{\partial}{\partial k} + \xi(k))P_9(y,t) = 0 \tag{10}$$

BoundaryCondition

$$P_1(0,t) = \tau_1 P_0(t) \tag{11}$$

$$P_2(0,t) = \tau_2^2 P_0(t) \tag{12}$$

$$P_3(0,t) = (\tau_1^2 + \tau_1^3 \tau_3)P_0(t) \tag{13}$$

$$P_4(0,t) = \tau_2 P_0(t) \tag{14}$$

$$P_5(0,t) = \tau_3 P_0(t) \tag{15}$$

$$P_6(0,t) = (\tau_3^2 + 2\tau_3^2 \tau_1)P_0(t) \tag{16}$$

$$P_7(0,t) = 2\tau_1 \tau_3 P_0(t) \tag{17}$$

$$P_8(0,t) = \tau_1^2 \tau_3 P_0(t) \tag{18}$$

$$P_9(0,t) = \tau_4 P_0(t) \tag{19}$$

InitialConditions

$$P_0(t) = \begin{cases} 1 & \text{initial} \\ 0 & \text{Otherwise} \end{cases} \tag{20}$$

We use the Laplace technique to solve the (1)-(10) equation. Now taking Laplace transfer of equation (1)-(19) with the help of equation (20), we get the following equation.

$$\left[s+\tau_1+\tau_2+\tau_3+\tau_4\right]\bar{P}_0(t)=\int_0^{\infty}\kappa_1\bar{P}_1(x,s)dx+\int_0^{\infty}\xi(y)\bar{P}_4(y,s)dy+ \int_0^{\infty}\kappa_3\bar{P}_5(z,s)dz+\int_0^{\infty}\xi(k)\bar{P}_9(k,s)dk+\int_0^{\infty}\xi(x)\bar{P}_3(x,s)dx+\int_0^{\infty}\xi(z)\bar{P}_6(z,s)dz \quad (21)$$

$$(s+\frac{\partial}{\partial x}+\tau_1+\tau_3+\kappa_1)\bar{P}_1(x,s)=0 \quad (22)$$

$$(s+\frac{\partial}{\partial x}+\tau_1+\tau_3+\kappa_1)\bar{P}_2(x,s)=0 \quad (23)$$

$$(s+\frac{\partial}{\partial x}+\xi(x))\bar{P}_3(x,s)=0 \quad (24)$$

$$(s+\frac{\partial}{\partial y}+\xi(y))\bar{P}_4(y,s)=0 \quad (25)$$

$$(s+\frac{\partial}{\partial z}+\tau_1+\tau_3+\kappa_3)\bar{P}_5(z,s)=0 \quad (26)$$

$$(s+\frac{\partial}{\partial z}+\xi(z))\bar{P}_6(z,s)=0 \quad (27)$$

$$(s+\frac{\partial}{\partial x}+\tau_3+2\kappa_1)\bar{P}_7(x,s)=0 \quad (28)$$

$$(s+\frac{\partial}{\partial x}+\tau_1+\kappa_3)\bar{P}_8(x,s)=0 \quad (29)$$

$$(s+\frac{\partial}{\partial k}+\xi(k))\bar{P}_9(k,s)=0 \quad (30)$$

Now taking Laplace's transfer of boundary conditions

$$\bar{P}_1(0,s)=\tau_1\bar{P}_0(s) \quad (31)$$

$$\bar{P}_2(0,s)=\tau_1^2\bar{P}_0(s) \quad (32)$$

$$\bar{P}_3(0,s)=\left(\tau_1^3+\tau_1^3\tau_3\right)\bar{P}_0(s) \quad (33)$$

$$\bar{P}_4(0,s)=\tau_2\bar{P}_0(s) \quad (34)$$

$$\bar{P}_5(0,s)=\tau_3\bar{P}_0(s) \quad (35)$$

$$\bar{P}_6(0,s)=(\tau_3^2+2\tau_3^2\tau_1)\bar{P}_0(s) \quad (36)$$

$$\bar{P}_7(0,s)=2\tau_1+\tau_3\bar{P}_0(s) \quad (37)$$

$$\bar{P}_8(0,s)=\tau_1^2\tau_3\bar{P}_0(s) \quad (38)$$

$$\bar{P}_9(0,s)=\tau_4\bar{P}_0(s) \quad (39)$$

Through the use of boundary conditions (31) to (39) and solving equations (22) to (30) using Laplace shifting properties. For calculating P_{up} and P_{down} with the help of a transition diagram. As we know that P_{up} is the probability for a good and partially failed state because the repair facility is available in our model, so the repair rate repairs a partially failed state, and it converts to an operable state. Below also used the total sum of probability theorem.

$$\bar{P}_{up}(s)=\bar{P}_0(s)+\bar{P}_1(s)+\bar{P}_2(s)+\bar{P}_5(s)+\bar{P}_7(s)+\bar{P}_9(s) \quad (40)$$

$$\bar{P}_{up}(s)=[1+\tau_1\{\frac{1-\bar{S_{\kappa_1}}(s+\tau_1+\tau_3)}{s+\tau_1+\tau_3}\}+\tau_1^2\{\frac{1-\bar{S_{\kappa_1}}(s+\tau_1+\tau_3)}{s+\tau_1+\tau_3}\}+ \tau_3\{\frac{1-\bar{S_{\kappa_3}}(s+\tau_1+\tau_3)}{s+\tau_1+\tau_3}\}+2\tau_3\tau_1\frac{1-S_{2\kappa_1}(s+\tau_3)}{S+\tau_3}\}+\tau_1^2\tau_3\{\frac{1-S_{\kappa_3}(s+\tau_1)}{S+\tau_1}\}]P_0(t) \quad (41)$$

$$\bar{P}_{down}(s)=1-\bar{P}_{up}(s) \quad (42)$$

7. Reliability Characteristic Analysis

7.1. Availability analysis of the system with general distribution

For calculating the availability of the system, we use general repair distribution. General repair distribution is defined as

$$\bar{P}_{\xi}(s) = \frac{\xi}{s+\xi} \tag{43}$$

Taking failure and repair rate as follows: $\tau_1 = 0.0001, \tau_2 = 0.0002, \tau_1 = 0.0001, \tau_3 = 0.0003, \tau_4 = 0.0004, \xi(x) = \xi(y) = \xi(z) = \xi(k) = \kappa_1(x) = \kappa_2(y) = \kappa_3(z) = \kappa_4(k) = 1$ Using the failure and repair rates mentioned above, use the inverse Laplace transfer of equation (41).

$$\begin{aligned} P_{up}(t) = 0.00012009e^{-1.00020005t} - 0.000000030029e^{-2.0001t} + \\ 0.0004793028e^{-1.00119998t} + 0.9994007089e^{-0.00000006985t} \end{aligned} \tag{44}$$

Table 1: *Availability analysis corresponding to time*

Time(t)In days	Availability
0	1
20	0.999399
40	0.999397
60	0.999396
80	0.999395
100	0.999393
120	0.999392
140	0.999390
160	0.999389
180	0.999388
200	0.999386

Time t=0,20,40,60,80,100,120,140,160,180 is considered to determine the system's availability, and Table 1 is provided.

7.2. Availability analysis of the system with Copula distribution

We use general repair and Copula repair distribution to calculate the system's availability. Copula repair distribution is defined as

$$S_{\alpha}(s) = \frac{exp[x^{\delta} + \{log\xi(x)\}^{\delta}]^{\frac{1}{\delta}}}{s + exp[x^{\delta} + \{log\xi(x)\}^{\delta}]^{\frac{1}{\delta}}} \tag{45}$$

General repair distribution is expressed as,

$$\bar{P}_{\xi}(s) = \frac{\xi}{s+\xi} \tag{46}$$

Taking failure and repair rate as follows: $\tau_1 = 0.0001, \tau_2 = 0.0002, \tau_1 = 0.0001, \tau_3 = 0.0003, \tau_4 = 0.0004, \xi(x) = \xi(y) = \xi(z) = \xi(k) = \kappa_1(x) = \kappa_2(y) = \kappa_3(z) = \kappa_4(k) = 1$ Using the failure and repair rates mentioned above, use the inverse Laplace transfer of equation (41)

$$\begin{aligned} \bar{P}_{up}(t) = 0.99977958e^{-0.0000000699t} - 0.00000030918e^{-1.0008t} \\ -0.00000002999e^{-2.0001t} + 0.0000000330e^{-2.718581739t} + 0.000220730e^{-2.71888215t} \end{aligned} \tag{47}$$

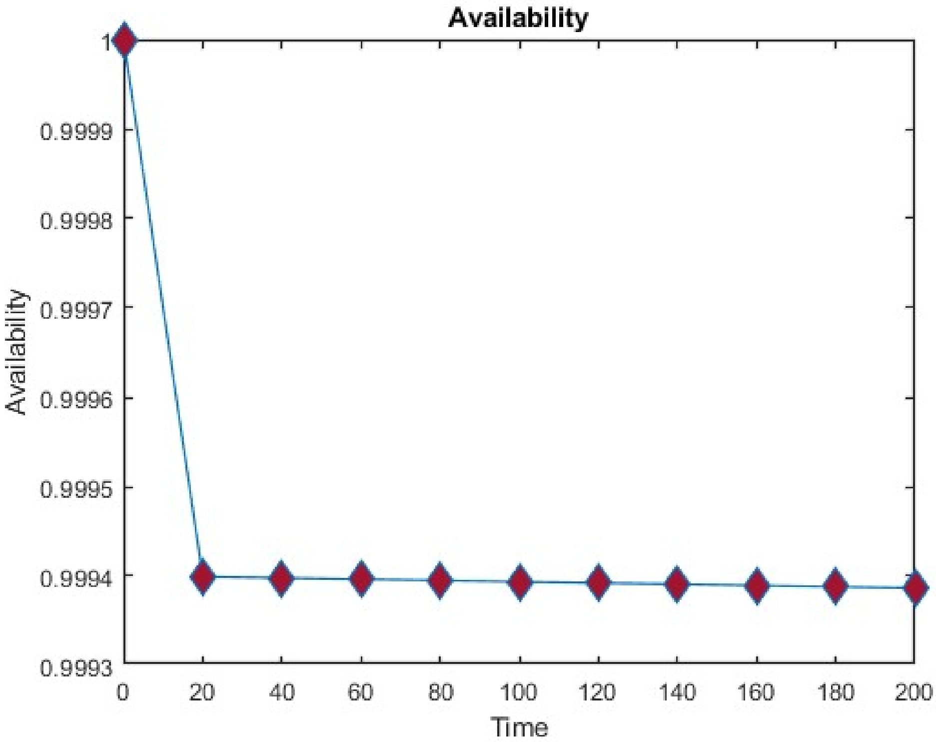

Figure 3: *Availability with general distribution*

Table 2: *Availability analysis with Copula repair corresponding to time*

Time(t)In days	Availability
0	1
20	0.999778
40	0.999776
60	0.999775
80	0.999773
100	0.999772
120	0.999771
140	0.999769
160	0.999768
180	0.999766
200	0.999765

Time t=0,20,40,60,80,100,120,140,160,180 is taken into consideration to determine the system's availability, and Table 2 is provided.

7.3. Reliability Analysis

When doing an analysis or evaluating the system's reliability, we'll assume there isn't a repair facility. In this instance, we assume that there is no repair facility. i.e., all repair rates are zero $\xi(x) = \xi(y) = \xi(z) = \xi(k) = \kappa_1(x) = \kappa_2(y) = \kappa_3(z) = \kappa_4(k) = 0$ and failure rate are $\tau_1 = 0.0001, \tau_2 = 0.0002, \tau_3 = 0.0003, \tau_4 = 0.0004$ Using equation (45) and (46), taking the Laplace transfer of equation (41). One can evaluate the reliability expression in (12) to the computed

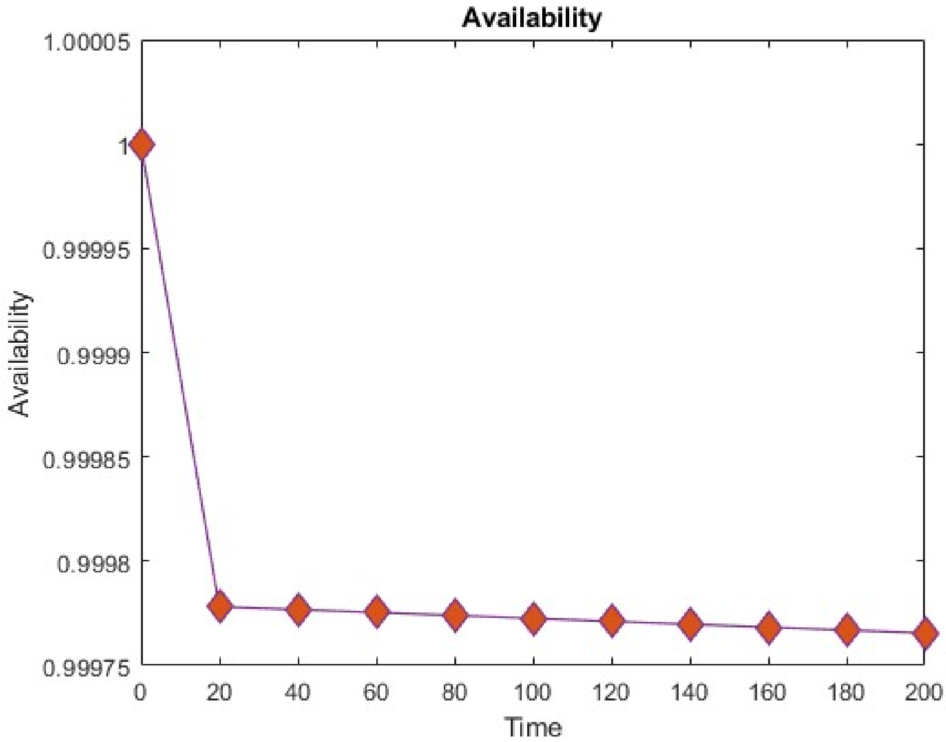

Figure 4: *Availability with Copula distribution*

values that are shown in Table 3.

$$R(t) = 0.000007e^{-0.00001t} + 0.66667e^{-0.00004t} + 0.3333250e^{-0.0001t} \tag{48}$$

Table 3: *Reliability analysis corresponding to Time*

Time(t)In days	Reliability
0	1.000
20	0.988
40	0.976
60	0.964
80	0.953
100	0.942
120	0.931
140	0.920
160	0.909
180	0.898
200	0.888

7.4. MEAN TIME TO FAILURE (MTTF) OF THE SYSTEM

The mean time to failure is the predicted time elapsed between the system's normal functioning and its first failure. Simply put, the average amount of time between system failures is known as the mean time to failure MTTF. In this, we considered that there is no repair facility. There we

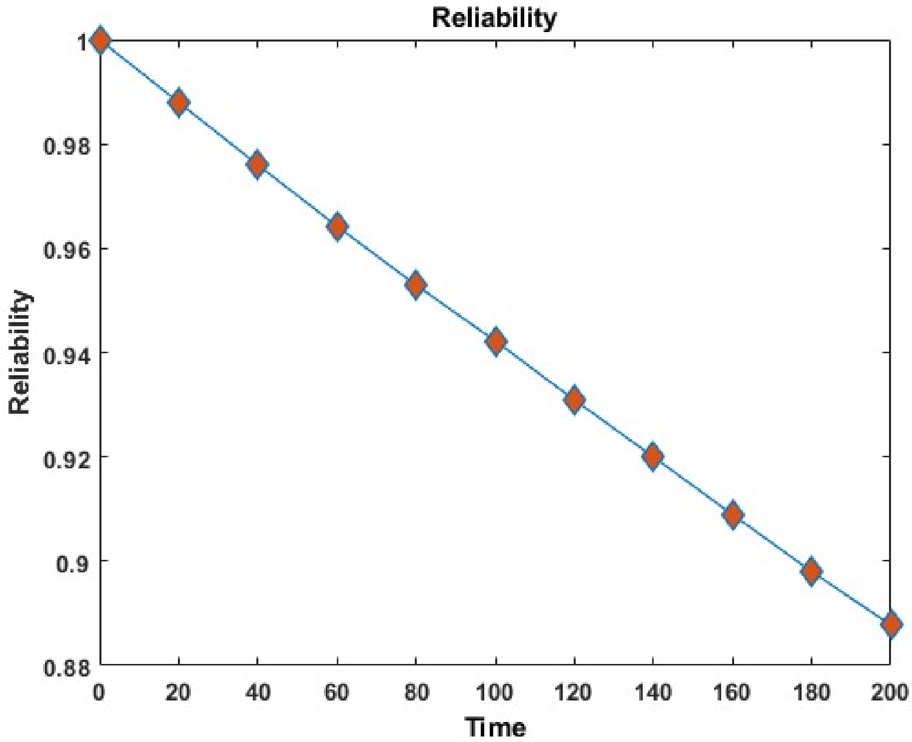

Figure 5: *Reliability Corresponding To Time*

assign all repair rate is zero, and in equation (45) limit tend to be zero; the MTTF of the system is obtained in equation (49).

$$MTTF = (\frac{\tau_1 + \tau_1^2 + \tau_3}{\tau_1 + \tau_3} + \frac{2\tau_1\tau_3}{\tau_3} + \frac{\tau_1^2\tau_3}{\tau_1})\frac{1}{\tau_1\tau_2\tau_3\tau_4} \quad (49)$$

Table 4: *System MTTF corresponding to failure rate*

Failure rate	MTTFτ_1	MTTFτ_2	MTTFτ_3	MTTFτ_4
0.0001	2000.2	2222.5	2500.3	2857.5
0.0002	1818.6	2000.2	2222.5	2500.3
0.0003	1667.3	1818.4	2000.2	2222.5
0.0004	1539.3	1666.9	1818.4	2000.2
0.0005	1429.5	1538.6	1666.8	1818.4
0.0006	1334.4	1428.7	1538.6	1666.9
0.0007	1251.2	1333.5	1428.7	1538.6
0.0008	1177.8	1250.1	1333.5	1428.7
0.0009	1112.5	1176.6	1250.1	1333.5

Fix the failure rate $\tau_1 = 0.001, \tau_2 = 0.002, \tau_3 = 0.003, \tau_4 = 0.004$ and fluctuate the failure rate. $\tau_1, \tau_2, \tau_3, \tau_4$ one after the other respectively as $\tau = 0.001, 0.002, 0.003, 0.004,$
$0.005, 0.006, 0.007, 0.008, 0.009$ is taken into consideration to determine the system's MTTF, and Table 4 is provided.

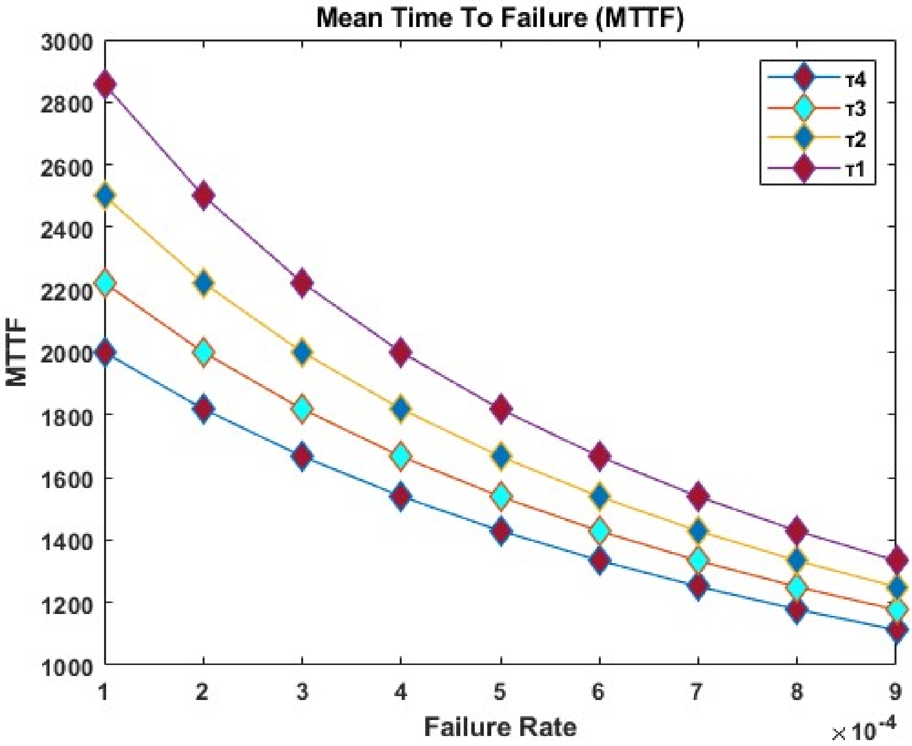

Figure 6: *MTTF Corresponding To Failure rate*

7.5. Analysis of sensitivity for the MTTF

Sensitivity analysis is the partial derivative of MTTF with respect to the failure rate. Now taking the partial derivative of the equation (49) with respect to the failure rate. The sensitivity analysis of the system is given below in Table 5

Table 5: *Sensitivity analysis corresponding to failure rate*

Failure rate	$\frac{\partial(MTTF)}{\tau_1}$	$\frac{\partial(MTTF)}{\tau_2}$	$\frac{\partial(MTTF)}{\tau_3}$	$\frac{\partial(MTTF)}{\tau_4}$
0.0001	$-19978 * 10^2$	$-24694 * 10^2$	$-31257 * 10^2$	$-40821 * 10^2$
0.0002	$-16509 * 10^2$	$-20002 * 10^2$	$-24695 * 10^2$	$-31254 * 10^2$
0.0003	$-13871 * 10^2$	$-16531 * 10^2$	$-20003 * 10^2$	$-24694 * 10^2$
0.0004	$-11819 * 10^2$	$-1389 * 10^2$	$-16531 * 10^2$	$-20002 * 10^2$
0.0005	$-1019 * 10^3$	$-11836 * 10^2$	$-13891 * 10^2$	$-16531 * 10^2$
0.0006	$-88767 * 10^1$	$-10205 * 10^2$	$-11836 * 10^2$	$-1389 * 10^3$
0.0007	$-78017 * 10^1$	$-88899 * 10^1$	$-10205 * 10^2$	$-11836 * 10^2$
0.0008	$-69108 * 10^1$	$-78134 * 10^1$	$-88899 * 10^1$	$-1.0205e + 06$
0.0009	$-61642 * 10^1$	$-69212 * 10^1$	$-78134 * 10^1$	$-88899 * 10^1$

7.6. COST AND PROFIT ANALYSIS FOR THE MODEL

***Case*1 :** Profit Analysis For The Model with General Distribution
when the capacity for the service is available; after that, the equation provides the predicted profit in the interval [0, t].

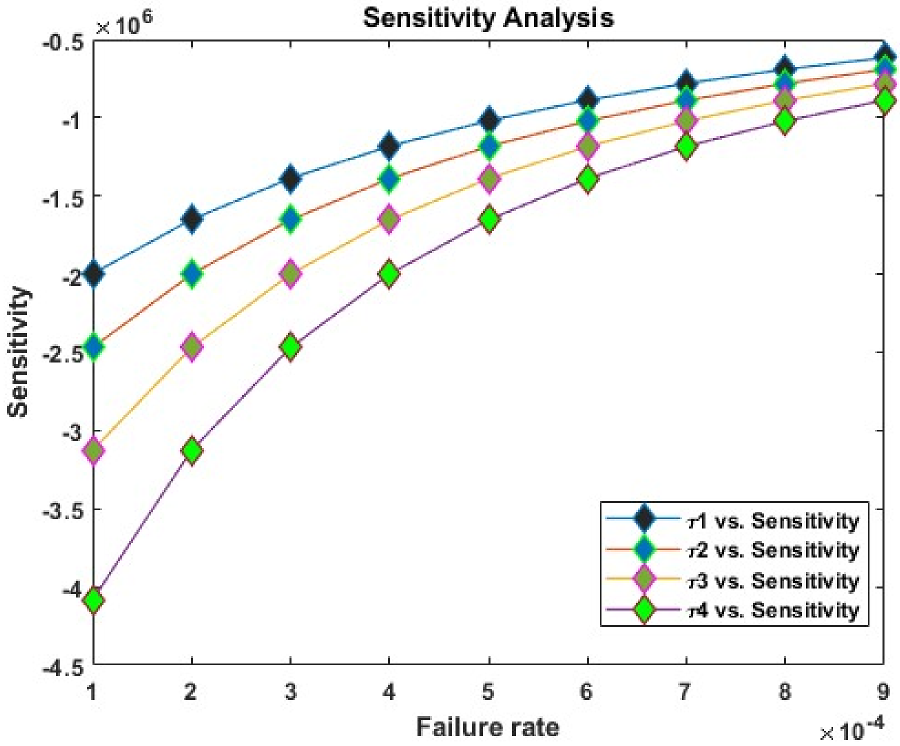

Figure 7: *Sensitivity Analysis Corresponding To Failure rate*

$$E_p(t) = C_1 \int_0^t P_{up}(t)dt - C_2 t. \tag{50}$$

Then using equation (44), equation (50) can be written as

$$E_p(t) = C1(2.5385 * 10^{-25} e^{-0.004t} - 5.3288 * 10^{-20} e^{-2252250286237519t} - 1.8937 * 10^{-16} e^{5277504776533377t} + 1.5014 * 10^{-8} e^{-2.0001t} - 4.7873 * 10^{-4} e^{-1.0012t} + 1.4308 * 10^{7}) - C2t \tag{51}$$

Assuming $C_1 = 1$ and $C_2 = 0.9, 0.8, 0.7, 0.6, 0.5$ and 0.4 respectively and t= 0,20,40,60,80,100,120,140 unit of time than expected profit is given in the Table 6 with the help of equation

Table 6: *Profit estimation with general distribution*

Time	$E_p(t), C_2 = 0.9$	$E_p(t), C_2 = 0.8$	$E_p(t), C_2 = 0.7$	$E_p(t), C_2 = 0.6$	$E_p(t), C_2 = 0.5$
0	0	0	0	0	0
20	1.9886	3.9886	5.9886	7.9886	9.9886
40	3.9766	7.9766	11.9766	15.9766	19.9766
60	5.9645	11.9645	17.9645	23.9645	29.9645
80	7.9524	15.9524	23.9524	31.9524	39.9524
100	9.94032	19.94032	29.94032	39.94032	49.94032
120	11.92818	23.92818	35.92818	47.92818	59.92818
140	13.9160	27.9160	41.9160	55.9160	69.9160
160	15.9038	31.9038	47.9038	63.9038	79.9038
180	17.8916	35.8916	53.8916	71.8916	89.8916

***Case*2 :** Profit Analysis For The Model with Copula Distribution

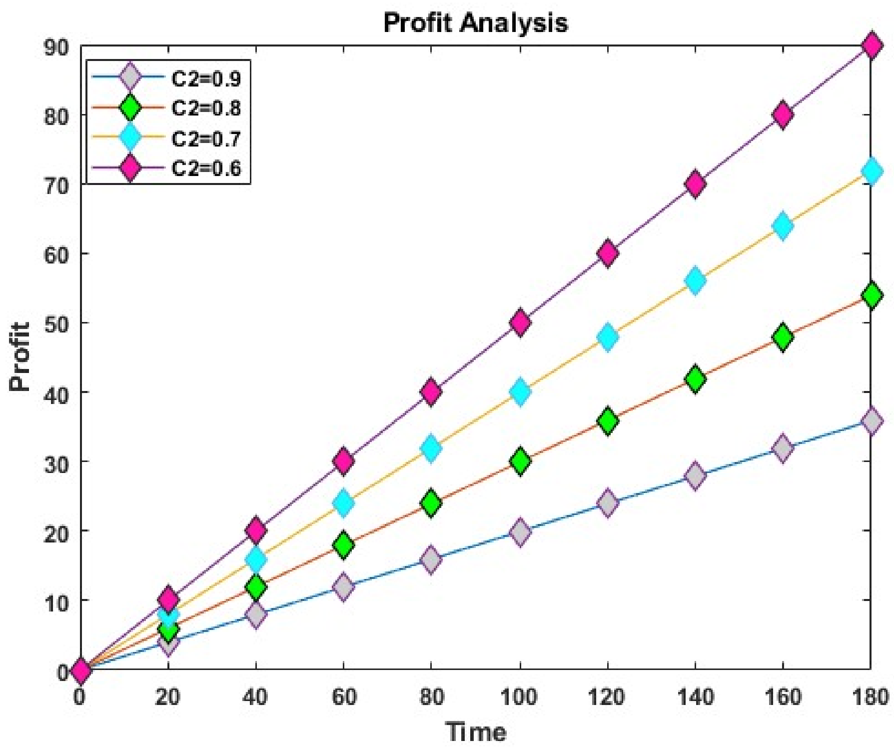

Figure 8: *Profit Corresponding to time with general distribution*

when the capacity for the service is available, thereafter, the equation provides the predicted profit in the interval [0, t].

$$E_p(t) = C_1 \int_0^t P_{up}(t)dt - C_2 t. \tag{52}$$

Then using equation (47), equation (52) can be written as

$$E_p(t) = C1(1.4992 * 10^{-18} e^{-2.0001t} - 1.2148 * 10^{-8} e^{-2.7186t} - 3.6164 * 10^{-5} \\ e^{6.1035t} - 1.4306 * 10^{7} e^{-6.9884*10^{-8}t} + 3.0894 * 10^{-7} e^{-1.0008t} + 1.4306 * 10^{7}) - C2 * t \tag{53}$$

Assuming $C_1 = 1$ and $C_2 = 0.9, 0.8, 0.7, 0.6, 0.5$ and 0.4 respectively and t= 0,20,40, 60,80,100,120,140 unit of time than expected profit is given in Table 7 with the help of equation

Table 7: *Profit estimation with Copula distribution*

Time	$E_p(t), C_2 = 0.9$	$E_p(t), C_2 = 0.8$	$E_p(t), C_2 = 0.7$	$E_p(t), C_2 = 0.6$	$E_p(t), C_2 = 0.5$
0	0	0	0	0	0
20	1.9957	3.9957	5.9957	7.9957	9.9957
40	3.9912	7.9912	11.991	15.991	19.991
60	5.9867	11.987	17.987	23.987	29.987
80	7.9822	15.982	23.982	31.982	39.982
100	9.9777	19.978	29.978	39.978	49.978
120	11.973	23.973	35.973	47.973	59.973
140	13.969	27.969	41.969	55.969	69.969
160	15.964	31.964	47.964	63.964	79.964
180	17.959	35.959	53.959	71.959	89.959

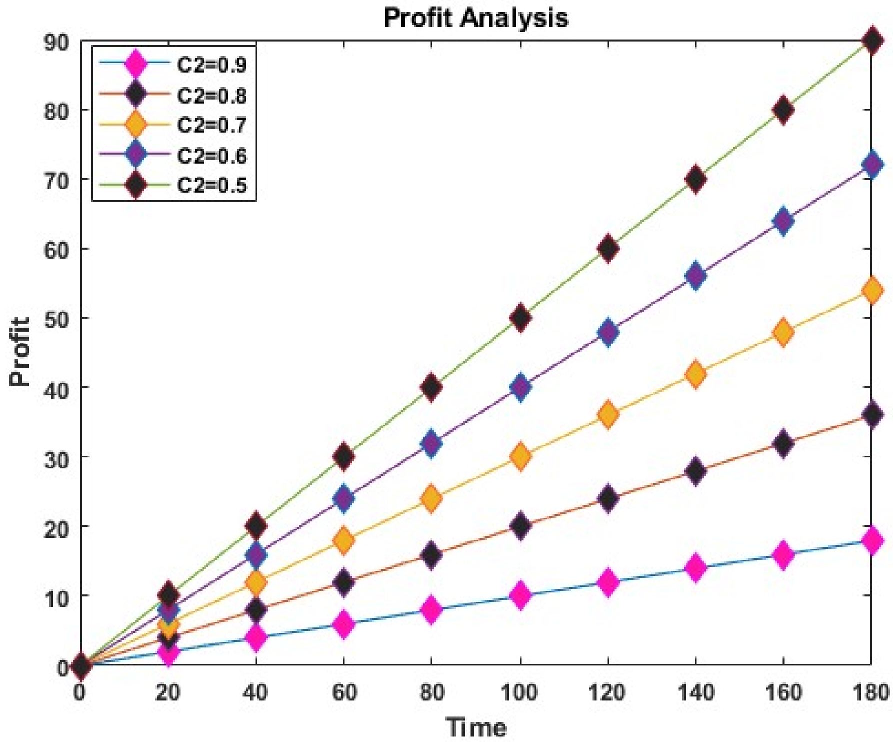

Figure 9: *Profit Corresponding to time with copula distribution*

8. Conclusion

When failures follow a general distribution, information on the system's availability is provided in Figure 3 and Table 1 for each time period. On the basis of it, we draw the conclusion that as time increases, system availability slowly decreases. When failures follow a copula distribution, information on the system's availability is provided in Figure 4 and Table 2 for each time period. On the basis of it, we draw the conclusion that as time increases, system availability slowly decreases. Tables 1 and 2 allow us to conclude that the copula distribution scheme provides more availability than the general distribution. We can predict system availability with respect to time using Tables 1 and 2. For a long time, system availability tends to be zero.

In the absence of a repair facility, information on the system's reliability is provided in Figure 5 and Tables 3 for each time period. On the basis of it, we draw the conclusion that as time increases, system reliability rapidly decreases. Figures 3,4 and 5 show that the system's performance is improved greatly when repair facilities are available.

Table 4 and Figure 6 provide information about the system's mean time to failure(MTTF); for the different failure rate parameters, MTTF gives different values. we draw the conclusion that as the failure rate increases, system MTTF rapidly decreases.

Sensitivity analysis for the MTTF corresponding to failure rate is shown in Table 5 and Figure 6. Tables 6 and 7 and Figures 8 and 9 show the system's profit and cost analysis corresponding to time; here, revenue cost C1=1 is fixed, and service cost(c2) is variable between 0.5 and 0.9. That leads us to the conclusion that the system's profit increases quickly whenever time increases while service costs remain low. The yield is larger when the service cost (c2) is 0.5, and the profit is lowest when the service cost is high (c2=0.9). Conclusion: To maximize profit, service costs must be kept to a minimum.

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