RELIABILITY AND PROFITABILITY ANALYSIS OF UTENSILS MANUFACTURING INDUSTRY WITH EFFECT OF TEMPERATURE AND PREVENTIVE MAINTENANCE

Manisha

•

Department of Mathematics, Maharshi Dayanand University, Rohtak, Haryana, India
manishagaba887@gmail.com

Dalip Singh

•

Department of Mathematics, Maharshi Dayanand University, Rohtak, Haryana, India
dsmdur@gmail.com

Kajal Sachdeva*

•

Department of Mathematics, Maharshi Dayanand University, Rohtak, Haryana, India
kajal.rs.maths@mdurohtak.ac.in

Sheetal

•

Department of Mathematics, Maharshi Dayanand University, Rohtak, Haryana, India
rtksheetal@gmail.com

*Corresponding Author

Abstract

The production stage of the manufacturing process contains numerous subsystems, and the failure of one might have an impact on the entire system. Thus, a manufacturing plant needs to be reliable and well-maintained. This paper examines the profitability and reliability of a production plant for utensils while taking the effect of temperature into account. The plant processes raw materials through several subsystems in series including cutting, pressing, spinning, and polishing & packing. Winter production requires a significant amount of heat which could damage the machinery. As a result, production is low and preventive maintenance is carried out during the winter. For both the summer and winter seasons, many system measures have been assessed. The time distributions have been assumed to be exponential. The model has been analysed using the Markov and Regenerative processes. The production fluctuation between the summer and winter seasons have been illustrated using a numerical example with specific values for the parameters.

Keywords: Utensils Manufacturing System; MTSF; Availability; Regenerative Point Technique, and Preventive Maintenance (PM).

1. Introduction

Companies are constantly adapting their organisational structures and competitive strategies to meet the many markets demands in today's world of global competition. They increase their capacity, long-term adaptability, and process sensitivity. The focus of entrepreneurial operations and strategies that promote adaptation to actual market needs has been the production system and its internal structures. The assessment and prediction of system reliability concerning the various operational process stages have grown in significance. For complex industrial systems, which typically have different failure modes, it is essential to create effective reliability evaluation tools to ensure appropriate performance under high and ambiguous demands.

Researchers have significantly improved the reliability analysis of manufacturing systems over time. Gupta and Tewari [1] investigated the performance analysis of a thermal power plant, which has four subsystems that operate at full capacity, below capacity, or fail. Rizwan et al. [2,3] provided a case study on a desalination plant that was shut down for annual maintenance during the winter for one month. Rahbi et al. [4] examined the reliability of a roading anode factory in the aluminium industry, where raw materials are routed via eight stations with a mix of series and parallel layouts. Manocha et al. [5] dealt with a system that had one database linked with a hot standby unit. Yusuf et al. [6] looked into the effectiveness of both online and offline preventive maintenance in repairing systems. Goyal et al. [7] studied the physical processing of a sewage treatment plant with five series-connected components. Rizwan et al. [8] examined the three pumps of a system delivering desalinated water to determine which pump was the least effective and required improvement for the system as a whole. Sachdeva et al. [9] analyse the sensitivity and reliability of membrane biofilm fuel cell. From all of these manufacturing plants, we took into account the utensil production plant to analyse reliability and profitability [10] as everyone needs efficient and appropriate utensils. Singh and Mahajan [11] examined the availability of the steel production facility, which includes systems for cutting, pressing, spinning, and polishing. Zaidi and Goya [12] studied the availability analysis of the cutting, furnance, hot-cold rolling, and roller furnisher series systems that make up the sheet formation system of the utensil manufacturing factory. Using a fuzzy technique, Kumar and Kumar [13] calculated the reliability of a production facility for utensils.

The profit analysis of the utensil manufacturing industry with the effect of temperature and preventative maintenance has yet to be examined. So, taking into account the impact of temperature, this article investigates the profitability and reliability of a manufacturing plant for utensils. The facility uses several subsystems to process raw materials, including cutting, pressing, spinning, polishing, and packing. Sheets are cut into circular shapes by cutting machines, and then they are pressed using different dies on a pressing machine according to the size and shape of various types of kitchenware. After that, sheets were sent out for spinning. A polished-ready product has been generated by the last stage of the process. Winter production requires a significant amount of heat, which could damage the machinery. As a result, production is low, and preventive maintenance is carried out during the winter.

The rest of the paper is organised as follow. Different notations, assumptions, and description of the system are included in Section 2. The stochastic model and its state transition probabilities are described in Section 3, along with a number of system metrics as well as a profit analysis of the system. The system measurements acquired using the graphs are examined in Section 4. Section 5 concludes with a few interesting interpretations.

2. System Description, Notations and Assumptions

Utensils manufacturing plants are widely used to produce various kinds of utensils. Utensils plant can have a variety of parts but mainly the plant consists for four subsystems like cutting system, pressing system, spinning system and polishing and packing system. Manufacturing of utensils entails the press or spin forming of metal, which frequently involves complex geometries with straight sides and as well as curves of various radii.

2.1. Description of the System

Sub-system C (Circle Cutting Machine)
As needed, sheets are cut into circular shapes.
Sub-system P (Pressing Machine)
The circle that was cut using a circular saw is now being sent to a pressing machine. Here, it is pressed using various dies in accordance with the size and shape of various types of kitchenware. Due to their shallow depth, some products, including as plates and bojanthal are ready for polishing right away.
Sub-system S (Spinning Machine)
According to their dies, the product created by pressing is sent for spinning. Some goods don't require further annealing before polishing, but others require it because of their deeper shapes. To eliminate contaminants, these items must be subjected to acid cleaning (Acid is a combination of Sulphuric and nitric acid).
Sub-system K (Polishing & Packing)
The final process has produced a product that is polished-ready. This stage involves packing and polishing the final product.

2.2. Notations

$m_1(t), M_1(t)$	probability and cumulative density functions by which the system go for preventive maintenance
$m_2(t), M_2(t)$	probability and cumulative density functions for completion of preventive maintenance time
$w_1(t), W_1(t)$	probability and cumulative density functions for changing the summer to winter season
$w_2(t), W_2(t)$	probability and cumulative density functions for changing the winter to summer season
a_1, a_2, a_3	rate of failure for subsystem C, P, S
b_1, b_2, b_3	rate of repair for subsystem C, P, S
O_{CPSK}	subsystem C, P, S, K operative
$F_C D_{PSK}$	subsystem C under repair and subsystem P, S, K under down state
$F_P D_{CSK}$	subsystem P under repair and subsystem C, S, K under down state
$F_S D_{CPK}$	subsystem S under repair and subsystem C, P, K under down state
$M_K D_{CPS}$	subsystem K under P.M. and subsystem C, P, S under down state
$\odot$	Laplace Stieltjes Convolution
©	Laplace Convolution

For other notations, refer [5].

2.3. Assumptions

- The failure and repair rates are independent and exponential in general.
- None of the sub-systems are experiencing simultaneous failures.
- Subsystem K has never failed.
- The repaired system works just like the new system.
- Subsystems are only repaired when they are in failed state.

3. Analysis of Model

The transition diagram of the system is given in Fig. 1.

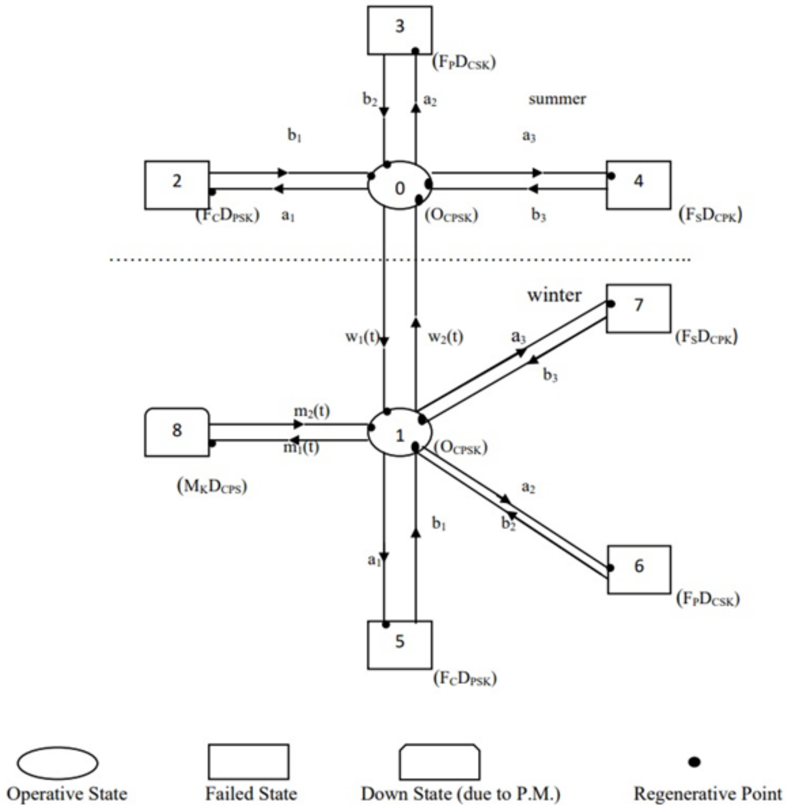

Figure 1: *State Transition Diagram*

Description of the Model and Transition Probabilities

3.1. Description of the model

Various states of the model for the system consisting four subsystems with season wise (summer and winter). The transition between states of system is shown in Fig. 1. States 0, 1, 2, 3, 4, 5, 6, 7, and 8 of the state transition diagrams are regeneration points. States 0 and 1 are the states where four subsystem work and so represents operative state during summer and winter respectively. States 2 and 5 are the states where the sub-system C go in failed states during summer and winter respectively so represents failed state. States 3 and 6 are the states where sub-system P go in failed states during summer and winter respectively so represents failed state. States 4 and 7 are the states where sub-system S go in failed states during summer and winter respectively so represents failed state. States 8 where sub-system K under preventive maintenance.

3.2. State Transition Probabilities

On the basis of state transition diagram, expressions for transition probabilities are given as follows:

$q_{01}(t) = e^{-(a_1+a_2+a_3)t} w_1(t)$ $\quad$ $q_{02}(t) = a_1 e^{-(a_1+a_2+a_3)t} \overline{W_1}(t)$

$q_{03}(t) = a_2 e^{-(a_1+a_2+a_3)t}\overline{W_1}(t)$ $q_{04}(t) = a_3 e^{-(a_1+a_2+a_3)t}\overline{W_1}(t)$
$q_{10}(t) = e^{-(a_1+a_2+a_3+)t}E_{10}(t)$ $q_{15}(t) = a_1 e^{-(a_1+a_2+a_3)t}E_{15}(t)$
$q_{16}(t) = a_2 e^{-(a_1+a_2+a_3)t}E_{15}(t)$ $q_{17}(t) = a_3 e^{-(a_1+a_2+a_3)t}E_{15}(t)$
$q_{18}(t) = e^{-(a_1+a_2+a_3)t}E_{18}(t)$ $q_{20}(t) = b_1 e^{-b_1 t}$
$q_{30}(t) = b_2 e^{-b_2 t}$ $q_{40}(t) = b_3 e^{-b_3 t}$
$q_{51}(t) = b_1 e^{-b_1 t}$ $q_{61}(t) = b_2 e^{-b_2 t}$
$q_{71}(t) = b_3 e^{-b_3 t}$ $q_{81}(t) = m_2(t)$

where

$E_{10}(t) = \overline{M_1}(t)w_2(t)$ $E_{15}(t) = \overline{M_1}(t)\overline{W_2}(t)$
$E_{18}(t) = m_1(t)\overline{W_2}(t)$

Transition probabilities $p_{ij}(t)$ from state i to state j can be calculated by taking Laplace transform of above obtained values of $q_{ij}(t)$ and then using the following mathematical relationship between p_{ij} and $q^*_{ij}(s)$
$p_{ij} = \lim_{s\to 0} q^*_{ij}(s)$
values of for all required combinations of i and j are obtained and the same are given as follows:

$p_{01} = w_1^*(a_1+a_2+a_3)$ $p_{02} = \frac{a_1}{(a_1+a_2+a_3)}[1 - w_1^*(a_1+a_2+a_3)]$
$p_{03} = \frac{a_2}{(a_1+a_2+a_3)}[1 - w_1^*(a_1+a_2+a_3)]$ $p_{04} = \frac{a_3}{(a_1+a_2+a_3)}[1 - w_1^*(a_1+a_2+a_3)]$
$p_{10} = E_{10}^*(a_1+a_2+a_3)$ $p_{15} = a_1 E_{15}^*(a_1+a_2+a_3)$
$p_{16} = a_2 E_{15}^*(a_1+a_2+a_3)$ $p_{17} = a_3 E_{15}^*(a_1+a_2+a_3)$
$p_{18} = E_{18}^*(a_1+a_2+a_3)$

Mean Sojourn time (μ_i)
If T_i denotes the stay time of the system in state i, then using the following mathematical relationship between μ_i and T_i
$\mu_i = \int_0^\infty P[T_i > t]dt$
values of μ_i for all required values of i are found, and the same are provided as:
$\mu_0 = \int_0^\infty e^{-(a_1+a_2+a_3)t}\overline{W_1}(t)dt$
$\mu_1 = \int_0^\infty e^{-(a_1+a_2)t}\overline{E_{15}}(t)$
$\mu_2 = \mu_5 = \frac{1}{b_1}$
$\mu_3 = \mu_{16} = \frac{1}{b_2}$
$\mu_4 = \mu_7 = \frac{1}{b_3}$
$\mu_8 = \int_0^\infty \overline{M_2}(t)dt$

The unconditional mean time (m_{ij}) which the system under consideration takes to move to state j where counting of the time starts as soon as it enters into state i can be obtained using the following mathematical relationship between m_{ij} and $q_{ij}(t)$
m_{ij}= $\int_0^\infty t q_{ij}(t)dt$,
values of for all required combinations of i and j thus obtained and given as follows:

$\mu_0 = m_{01} + m_{02} + m_{03} + m_{04};$ $\mu_1 = m_{10} + m_{15} + m_{16} + m_{17} + m_{18}$
$\mu_2 = m_{20};$ $\mu_3 = m_{30}$
$\mu_4 = m_{40};$ $\mu_5 = m_{51};$
$\mu_6 = m_{61}$ $\mu_7 = m_{71};$
$\mu_8 = m_{81}$

4. System Performance Measures

4.1. Mean Time to System Failure

We retain failed states as absorbing states in order to calculate the system's MTSF. Using recursive relations for $\phi_i(t)$ can be obtained and the same are given as:
$\phi_0(t) = Q_{01}(t) \odot \phi_1(t) + Q_{02}(t) + Q_{03}(t) + Q_{04}(t)$
$\phi_1(t) = Q_{10}(t) \odot \phi_0(t) + Q_{15}(t) + Q_{16}(t) + Q_{17}(t) + Q_{18}(t) \odot \phi_8(t)$
$\phi_8(t) = Q_{81}(t) \odot \phi_1(t)$
By solving these relations for $\phi_0^{**}(s)$ using the Laplace Stieltjes transformation of these relations, we get
$\phi_0^{**}(s) = \frac{N(s)}{D(s)}$,
where
$N(s) = (q_{02}^*(s) + q_{03}^*(s) + q_{04}^*(s))(1 - q_{18}^*(s)q_{81}^*(s)) + q_{01}^*(s)(q_{15}^*(s) + q_{16}^*(s) + q_{17}^*(s))$
$D(s) = 1 - q_{01}^*(s)q_{10}^*(s) - q_{18}^*(s)q_{81}^*(s)$
Using above calculated value of $\phi_0^{**}(s)$, MTSF can be obtained when the system under consideration starts from the state 0 and the same is given as follows:
$T_0 = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{N}{D}$,
where
$N = \mu_0[1 - p_{18}] + \mu_1 p_{01} + \mu_8 p_{01} p_{18}$
$D = 1 - p_{01}p_{10} - p_{18}$

4.2. Availabilities in Summer and Winter

During Summer
To determine the availability in summer $AS_0(t)$ of the system, recursive relations thus obtained using probabilistic arguments, are given as:
$AS_0(t) = M_0(t) + q_{01}(t)©AS_1(t) + q_{02}(t)©AS_2(t) + q_{03}(t)©AS_3(t) + q_{04}(t)©AS_4(t)$
$AS_1(t) = q_{10}(t)©AS_0(t) + q_{15}(t)©AS_5(t) + q_{16}(t)©AS_6(t) + q_{17}(t)©AS_7(t) + q_{18}(t)©AS_8(t)$
$AS_2(t) = q_{20}(t)©AS_0(t)$
$AS_3(t) = q_{30}(t)©AS_0(t)$
$AS_4(t) = q_{40}(t)©AS_0(t)$
$AS_5(t) = q_{51}(t)©AS_1(t)$
$AS_6(t) = q_{61}(t)©AS_1(t)$
$AS_7(t) = q_{71}(t)©AS_1(t)$
$AS_8(t) = q_{81}(t)©AS_1(t)$
where,
$M_0(t) = e^{-(a_1+a_2+a_3)t}\overline{W_1}(t)$
By solving these relations for $AS_0^*(s)$ using the Laplace transform of these relations, we get
$AS_0^*(s) = \frac{N_1(s)}{D_1(s)}$
where,
$N_1(s) = M_0^*(s)[1 - q_{15}^*(s)q_{51}^*(s) - q_{16}^*(s)q_{61}^*(s) - q_{17}^*(s)q_{71}^*(s) - q_{18}^*(s)q_{81}^*(s)]$
$$D_1(s) = [q_{02}^*(s)q_{20}^*(s) + q_{03}^*(s)q_{30}^*(s) + q_{04}^*(s)q_{40}^*(s)][q_{15}^*(s)q_{51}^*(s) + q_{16}^*(s)q_{61}^*(s) + q_{17}^*(s)q_{71}^*(s) + q_{18}^*(s)q_{81}^*(s)] - [q_{02}^*(s)q_{20}^*(s) + q_{03}^*(s)q_{30}^*(s) + q_{04}^*(s)q_{40}^*(s) + q_{15}^*(s)q_{51}^*(s) + q_{16}^*(s)q_{61}^*(s) + q_{17}^*(s)q_{71}^*(s) + q_{18}^*(s)q_{81}^*(s)] + 1$$
Using above calculated value of $AS_0^*(s)$ availability in summer can be obtained in steady-state and the same is given as follows:
$AS_0 = \lim_{s\to 0} sAS_0^*(s) = \frac{N_1}{D_1}$
where,
$N_1 = \mu_0 p_{10}$
$D_1 = (\mu_0 + \mu_2 p_{02} + \mu_3 p_{03} + \mu_4 p_{04})p_{10} + (\mu_1 + \mu_5 p_{15} + \mu_6 p_{16} + \mu_7 p_{17} + \mu_8 p_{18})p_{01}$

During Winter
Similarly, steady-state availability during winter are given as follows:
$AW_0 = \lim_{s \to 0} sAW_0^*(s) = \frac{N_2}{D_1}$
where,
D_1 already defined and
$N_2 = \mu_1 p_{01}$

4.3. Busy Period Analysis

Busy period of the repairman due to repair in summer
Similarly, steady-state Busy period of the repairman due to repair in summer are given as follows:
$BS_0 = \lim_{s \to 0} sBS_0^*(s) = \frac{N_3}{D_1}$
where,
D_1 already defined and
$N_3 = (\mu_2 p_{02} + \mu_3 p_{03} + \mu_4 p_{04}) p_{10}$
During Winter
Similarly, steady-state Busy period of the repairman due to repair in winter are given as follows:
$BW_0 = \lim_{s \to 0} sBW_0^*(s) = \frac{N_4}{D_1}$
where,
D_1 already defined and
$N_4 = (\mu_5 p_{15} + \mu_6 p_{16} + \mu_7 p_{17}) p_{01}$

4.4. Expected Number of Visits of the Repairman for Repair

During summer
Similarly, steady-state number of visits of the repairman during summer are given as follows:
$VS_0 = \lim_{s \to 0} sVS_0^*(s) = \frac{N_5}{D_1}$
where,
D_1 already defined and
$N_5 = p_{10}(1 - p_{01})$
During Winter
Similarly, steady-state number of visits of the repairman during winter are given as follows:
$VW_0 = \lim_{s \to 0} sVW_0^*(s) = \frac{N_6}{D_1}$
where,
D_1 already defined and
$N_6 = p_{01}(1 - p_{10} - p_{18})$

4.5. Expected Number of Visits of the Repairman for Preventive Maintenance

Similarly, steady-state number of visits of the repairman for preventive maintenance are given as follows:
$PM_0 = \lim_{s \to 0} sPM_0^*(s) = \frac{N_7}{D_1}$
where,
D_1 already defined and
$N_7 = p_{01} p_{18}$

5. Cost-Benefit Analysis

Profit of the system under consideration can be obtained by subtracting the costs due to repair, per visit charges of the repairman for repair in summer and winter and per visit charges of the repairman for preventive maintenance. The same can expressed in terms of the various performance measures obtained through the model developed in this given as follows:
$Profit = CS_0AS_0 + CW_0AS_0 - CS_1BS_0 - CW_1BW_0 - CS_2VS_0 - CW_2VW_0 - C_3PM_0$
where,
CS_0 : revenue during summer, per unit uptime
CW_0 : revenue during winter, per unit uptime
CS_1 : revenue during summer per unit time for repair
CW_1 : revenue during winter per unit time for repair
CS_2 : Cost per visit during summer for repair
CW_2 : Cost per visit during winter for repair
C_3 : Cost per visit for preventive maintenance

6. Numerical Interpretation

Let us assume particular value as:

$w_1(t) = \alpha e^{-\alpha t}$ $\quad w_2(t) = \beta e^{-\beta t}$
$m_1(t) = \gamma e^{-\gamma t}$ $\quad m_2(t) = \delta e^{-\delta t}$
$p_{01} = \frac{\alpha}{a_1+a_2+a_3+\alpha}$ $\quad p_{02} = \frac{a_1}{a_1+a_2+a_3+\alpha}$
$p_{03} = \frac{a_2}{a_1+a_2+a_3+\alpha}$ $\quad p_{04} = \frac{a_3}{a_1+a_2+a_3+\alpha}$
$p_{10} = \frac{\beta}{a_1+a_2+a_3+\gamma+\beta}$ $\quad p_{15} = \frac{a_1}{a_1+a_2+a_3+\gamma+\beta}$
$p_{16} = \frac{a_2}{a_1+a_2+a_3+\gamma+\beta}$ $\quad p_{17} = \frac{a_3}{a_1+a_2+a_3+\gamma+\beta}$
$p_{18} = \frac{\gamma}{a_1+a_2+a_3+\gamma+\beta}$ $\quad p_{20} = p_{30} = p_{40} = p_{51} = p_{61} = p_{71} = p_{81} = 1$
$\mu_0 = \frac{1}{a_1+a_2+a_3+\alpha}$ $\quad \mu_1 = \frac{1}{a_1+a_2+a_3+\beta+\gamma}$
$\mu_2 = \frac{1}{b_1}$ $\quad \mu_3 = \frac{1}{b_2}$
$\mu_4 = \frac{1}{b_3}$ $\quad \mu_5 = \frac{1}{b_1}$
$\mu_6 = \frac{1}{b_1}$ $\quad \mu_7 = \frac{1}{b_3}$
$\mu_8 = \frac{1}{\delta}$

where
$a_1 = 0.635, a_3 = 0.3589, a_2 = 0.781, b_1 = 0.887, b_2 = 0.793, b_3 = 0.821, \alpha = 0.815, \beta = 0.013,$
$\gamma = 0.937, \delta = 0.870, CS_0 = 15000, CS_1 = 1500, CW_0 = 15000, CW_1 = 1600, CS_2 = 1450,$
$CW_2 = 1550, C3 = 1400.$
Various graphs have been plotted but all the graphs have not been shown here to use minimum space and to avoid repetition of similar interpretations. However, the users of such systems may plot graph of their interest as per the requirement and may take important decision regarding profitability of the system. Regarding the availability and nature of MTSF, various rates have been depicted as shown in Fig. 2 and 3 which reveal that MTSF and Availability decreases as failure rates increases. However, their values go in the direction δ and b_2. Some of the plotted graphs are shown as follows:
The MTSF behaviour for varied δ is given in Fig. 2. MTSF decreases as the failure rate value (a_2) rises. Higher values of δ correspond to higher values in it.

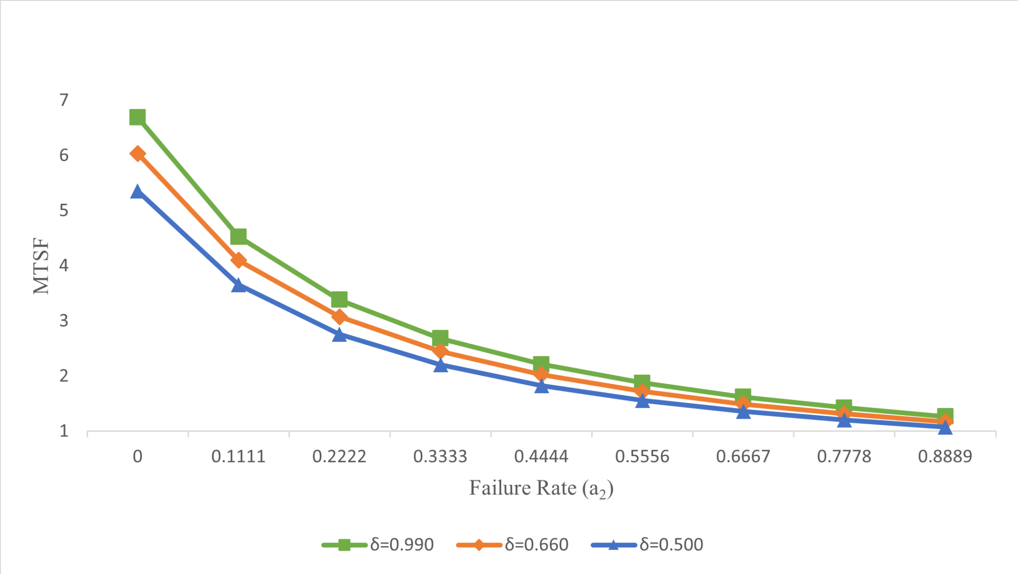

Figure 2: *MTSF versus Failure Rate* (a_2) *for different values of* (δ)

The availability behaviour in the summer and winter w.r.t. failure rate is shown in Fig. 3. Summer availability and winter availability both declines as the value of the failure rate rises (a_2). Also, the system is available more in summer than winter season.

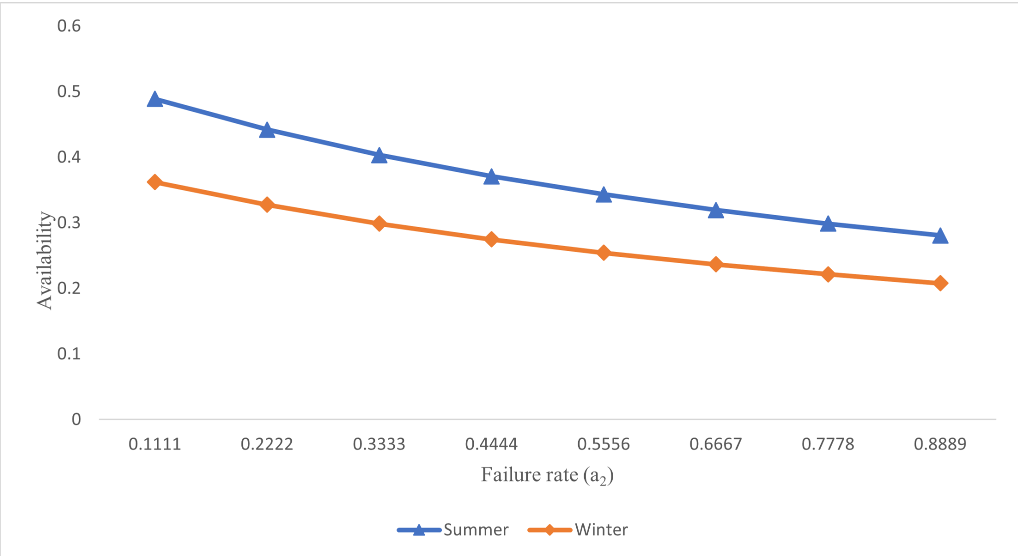

Figure 3: *Availability in Summer and Winter for different values of Failure rate* (a_2)

The way that profit acts in relation to revenue in the summer (CS_0) for various values of the cost paid for repair in the summer (CS_1) is shown in Fig. 4. As revenue values rise in the summer, profit rises as well (CS_0). Additionally, it has been seen that as (CS_1) values rise, the profit falls.

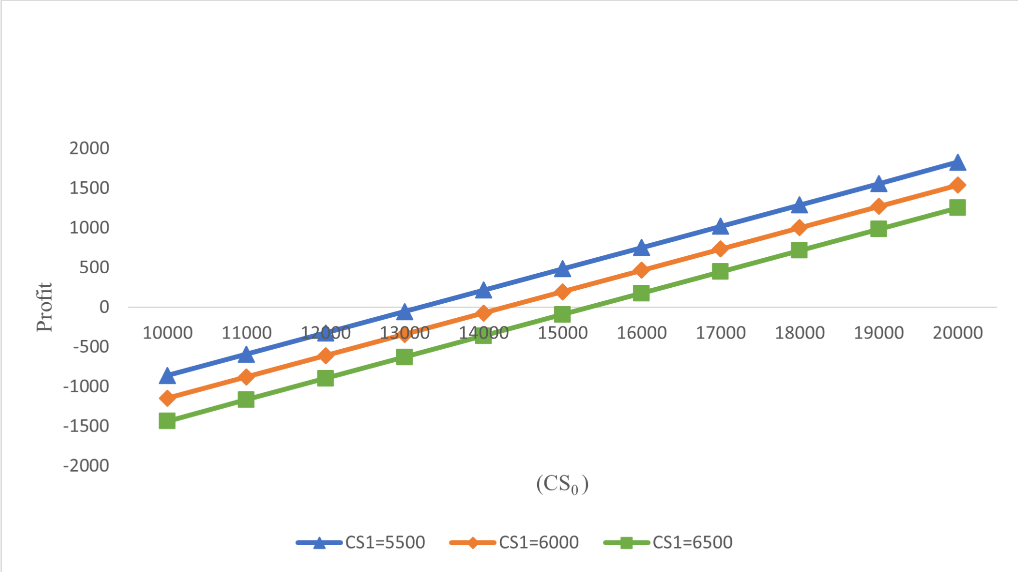

Figure 4: *Profit versus revenue in summer (CS_0) for different values of cost paid for repair in summer (CS_1)*

The relationship between profit and revenue in winter (CW_0) for various values of cost paid for repair in winter (CW_1) is shown in Fig. 5. With an increase in winter revenue values, profit rises (CW_0). Additionally, it has been noted that as (CW_1) values rise, the profit falls.

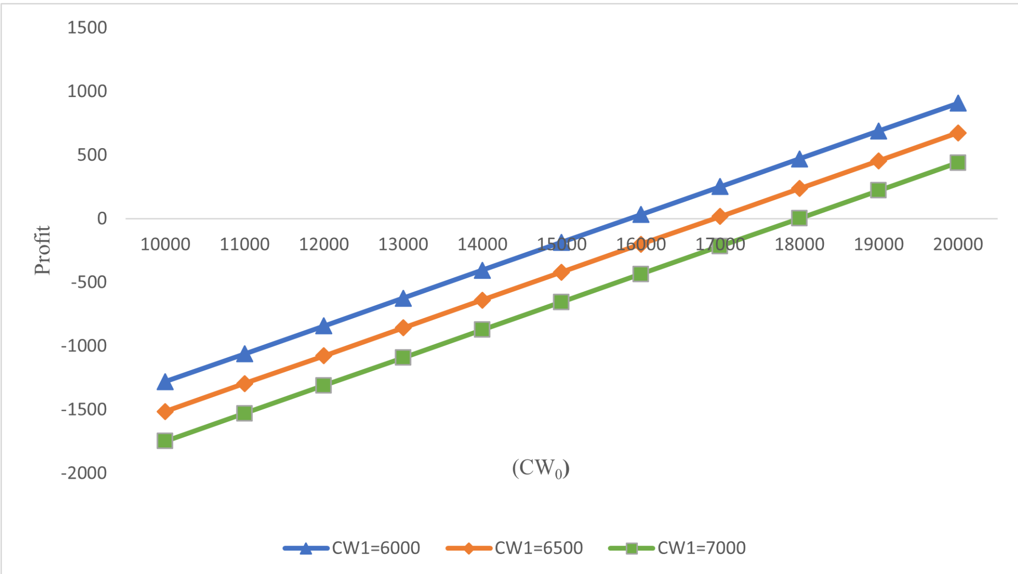

Figure 5: *Profit versus revenue in winter (CW_0) for different values of cost paid for repair in winter (CW_1)*

Fig. 6 illustrates the behaviour of profit in relation to revenue during the winter (CW_0) for various costs associated with preventive maintenance (C_3). With an increase in winter revenue values, profit rises (CW_0). Additionally, it has been seen that as (C_3) values rise, the profit falls.

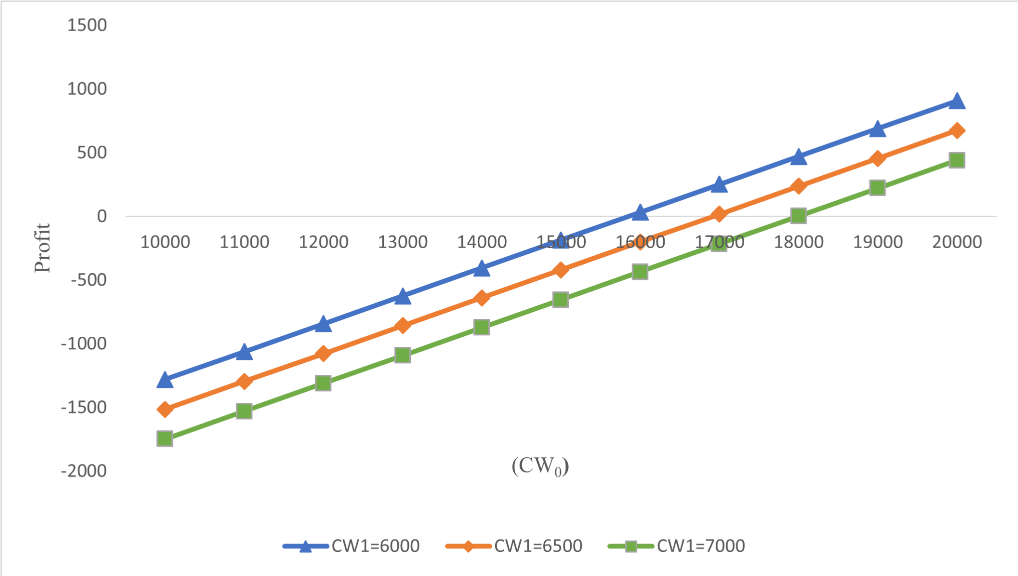

Figure 6: *Profit versus revenue in winter* (CW_0)*for different values of cost paid for Preventive Maintenance* (C_3)

Values of parameters taken and cut-off points obtained from the above figures are tabulated as follows:

Fig	Varied Parameters	Condition	Interpretation
4	CS_1 = 5500	CS_0> 13202.0841	System is profitable
	CS_1 = 6000	CS_0> 14270.9341	System is profitable
	CS_1 = 6500	CS_0> 15339.7841	System is profitable
5	CW_1 =6000	CW_0>15848.2632	System is profitable
	CW_1 =6500	CW_0>16917.2760	System is profitable
	CW_1 =7000	CW_0>17986.2888	System is profitable
6	C_3 = 5000	CW_0>10842.1274	System is profitable
	C_3 = 6000	CW_0>11778.9029	System is profitable
	C_3 = 7000	CW_0>12716.0337	System is profitable

7. Conclusion

In the current study, profitability and reliability of a production plant for utensils is analysed while taking the effect of temperature into account. The system is available more in summer than winter season. The findings for a specific situation demonstrate the relevance of research since cut-off points may be used to set lower and upper limits for a variety of factors. For instance, setting a product's pricing so that the system is profitable depends on the cut-off point for revenue per unit uptime. The cut-off points facilitate many crucial judgments for the profits according to revenue.

Funding

The first author delightedly acknowledges the University Grants Commission (UGC), New Delhi, India for providing financial support.

Disclosure statement

The authors declare that they have no conflict of interest.

References

[1] Gupta, S., and Tewari, P. C. (2009). Simulation modeling and analysis of a complex system of a thermal power plant. *J Ind. Eng. Manag*, 387–406.

[2] Rizwan, S. M., Padmavathi, N., Anita, P. and Taneja, G., (2013). Reliability Analysis of a Seven Unit Desalination Plant with Shutdown During Winter Season and Repair / Maintenance on FCFS Basis. *International Journal of Performability Engineering*, 523–528.

[3] Rizwan, S. M., Thanikal, J. and Torrijos, M., (2014). A general model for reliability analysis of a domestic wastewater treatment plant. *International Journal of Condition Monitoring and Diagnostic Engineering Management* , 3–6.

[4] Al Rahbi, Y., Rizwan, S. M., Alkali, B., Cowell, A. and Taneja, G., (2017). ., Reliability analysis of rodding anode plant in aluminum industry. *International Journal of Applied Engineering Research* , 5616–5623.

[5] Manocha, A., Taneja, G., Singh, S. and Rishi R., (2019). Modelling and analysis of two-unit hot standby database system with random inspection of standby unit. *International Journal of Mathematics in Operational Research*, 156–180.

[6] Yusuf, I., Yusuf, B. and Suleiman, K.,(2019)., Reliability assessment of a repairable system under online and offline preventive maintenance *Life Cycle Reliability and Safety Engineering* , 1–16.

[7] Goyal, D., Kumar, A., Saini, M. and Joshi, H., (2019). Reliability, maintainability and sensitivity analysis of physical processing unit of sewage treatment plant. *SN Appl. Sci.* , 1507.

[8] Rizwan, S. M., Sachdeva, K., Alagiriswamy, S. and Al Rahbi, Y., (2023). Performability and Sensitivity Analysis of the Three Pumps of a Desalination Water Pumping Station. *International Journal of Engineering Trends and Technology* , 51(2): 283–292.

[9] Rizwan, S. M., Sachdeva, K., Al Balushi, N., Al Rashdi, S., and Taj, S. Z., (2023) Reliability and Sensitivity Analysis of Membrane Biofilm Fuel Cell. *International Journal of Engineering Trends and Technology* , 71(3): 73–80.

[10] Sachdeva, K., Taneja, G., and Manocha, A., (2022). Sensitivity and economic analysis of an insured system with extended conditional warranty. *Reliability: Theory & Applications*,315–327.

[11] Singh, J., and Mahajan, P., (1999). Reliability of utensils manufacturing plant-a case study. *Opsearch* , 13(24): 260–269.

[12] Zaidi, Z., and Goya, Y. K., (2012). Availability Analysis of Sheet Formation System of the Utensils Industry Mathematical View. *International Transactions in Applied Sciences* , 214–220.

[13] Kumar, K., and Kumar, P., (2010). Mathematical modeling and analysis of stainless steel utensil manufacturing unit using fuzzy reliability. . *International Journal of Engineering Science and Technology* , 2370–2376.