Assessment of Reliability Factors in Chocolate Manufacturing Plant using Boolean Function Technique and Neural Networking.

Anil Chandra, Surbhi Gupta, Anjali Naithani

Abstract: A simple approach of solving a mathematical model depicting the reliability of a system is by doing its mathematical formulation using Boolean algebra technique and neural networking approach in simplification of complex system. Various reliability parameters are computed on applying Boolean and neural network approach. The author focuses in this paper is to calculate the cost and factors of reliability of chocolate manufacturing plant using feed forward neural network approach using MATLAB.

Keyword: Cost factor, Exponential distribution, Feed forward network, Neural Network, Neural weights, Reliability modeling, Weibull distribution.

I. INTRODUCTION

Earlier in reliability analysis of the system the various measures of the system effectiveness obtained were considered as precise value but practically there is some uncertainty in data either due to human error or due to the data is recorded. Further complexity of system escalates the degradation of functioning of system. The primary objective of reliability analysis is to predict the future life of the system by analyzing present functioning of the system. Different repair strategies undertaken, affects the system reliability in various ways. The social control of system confide on the judgement taken throughout coming up with, implementing in operation and maintaining. Several researcher studied the price and liableness of system earlier[3,4,5,7]. For complex system, it is tedious to solve the mathematical equations using the traditional approach. To tackle such problems, various soft computing methods like fuzzy logic etc. have been used earlier[7]. N. Karunanithi, D. Whitley [8] explain the concept of neural network in reliability. Ekta .Neeraj gupta[9] apply neural network to find reliability of marine vehicle. Biological neuron system can be simplified to neural networks.

We can recognize a neural network by three of its component such as neuron, network architecture and learning algorithm. We can non linearly transform a multi dimensional input variable into multidimensional output variable using feed forward neural network architecture. There are three main parts of such transformation:
1) The input layer, it is the first part and communicates with environment.
2) The hidden layer, it is the enter mediatory layer.
3) Output layer, it gives the results to the user. These layers are connected through links with weights. The process of adjusting these weights to minimize the error is discussed in learning algorithm. The complexity of the system can be reduced using the method as these network automatically recognize the relationship between data. Therefore it is very useful for modeling keeping these facts in mind, the model for chocolate manufacturing plant is studied by author.

II. SYSTEM DISCRIPTION

The production of chocolate involves various steps and hence each of which has related process factors which influence the productivity of the procedure and the various characteristics associated to the chocolate.

Selection of cocoa beans: - The randomly selected beans are analysed by the method accepted by the international standards organisation and the samples go cut tests.

Fermentation : -They are either put in substantially shallow, warmed plate or covered with expansive banana leaves.

Drying : -The drying process usually results in seeds that are about half of their original weight.

Roasting :-The shells of the beans is removed, and the inward cocoa bean meat is converted into little pieces called "cocoa nibs."

Winnowing: - The cooking procedure makes the covering of the cocoa seeds very weak, and cocoa nibs are made to go through a progression of sieves, which strain and sort the nibs as per measure.

Grinding :-By this procedure of grinding those nibs of cocoa are transformed into “cocoa alcohol” or “cocoa liquor”.

Pressing :-cocoa butter is extracted by cocoa mass.

Milling:• using milling cutter the material is removed from the surface of work station.

Mixing :-To enhance the flavour and the texture, through mixing is carried out.
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Coaching:- the mixing, agitating, and aerating of liquid chocolate is done using this process. The chocolate manufacturing plant under consideration here consist of 17 subsystems. Subsystem $\mu_1$ consists of selected cocoa beans which are in standby i.e. when the main unit “$\mu_1$” is in action, the standby unit “$\mu_2$” forced into operation. Further the processes are carried out in the subsystems $\mu_3$, $\mu_4$, $\mu_6$ an $\mu_7$ that are drying, cleaning, roasting and winnowing respectively. After this process of grinding of the cocoa beans takes place in the subsystem $\mu_7$. At the subsystem $\mu_7$ we have the choice of converting the beans into cocoa powder through the processes of milling and sieving carried out by subsystems $\mu_{10}$ and $\mu_{11}$ respectively or we can carry out the further process of extracting the fine chocolate through the manufacturing plant. In this case after the grinding of cocoa beans in subsystem $\mu_7$ the cocoa nibs are converted to cocoa butter in the subsystem $\mu_{12}$. The cocoa butter is mixed with milk in subsystem $\mu_{13}$ or grinded once more without milk in the subsystem $\mu_{14}$. After this the grounded cocoa butter is perfectly conched in the subsystem $\mu_{15}$. Furthermore, the resulting solid chocolate is enrobed in thin layers in the subsystem $\mu_{16}$. Finally the panning is done to give the product shiny finishing the subsystem $\mu_{17}$.

SECTION I
In this section we apply Boolean technique to evaluate reliability and M.T.T.F.

III. ASSUMPTIONS
- In starting all units are fully operable.
- The component of all states is either operable or partially operable.
- No repair facility is provided.
- System conditions individually are statistically independent..
- In advance we know all component reliability.
- All components follow arbitrary failure time.
- The element which provide supply between two components considered as fully reliable.

IV. NOTATIONS USED

$\mu_1$ = selection of cocoa beans
$\mu_2$ = fermentation
$\mu_3$ = drying
$\mu_4$ = cleaning
$\mu_5$ = roasting
$\mu_6$ = winnowing
$\mu_7$ = grinding
$\mu_8$ = pressing
$\mu_9$ = milling
$\mu_{10}$ = sieving
$\mu_{11}$ = cocoa powder
$\mu_{12}$ = cocoa butter
$\mu_{13}$ = mixing
$\mu_{14}$ = grinding
$\mu_{15}$ = couching
$\mu_{16}$ = enrobing
$\mu_{17}$ = panning
$\lor$ : symbol of logical matrix.

G: $i^{th}$ part system reliability
For all $i = 1, 2, .. .17$.

G: whole system reliability.

G: Reliability when it follows weibull distribution.

G: Reliability when failure rate follows exponential distribution.

V. MATHEMATICAL MODEL

VI. FORMULATION OF MATHEMATICAL MODEL

After applying technique of Boolean function the chances of successfully operation of system are expressed in logical matrix.

$$F(\mu_1, \mu_2, .. . \mu_{17}) = \begin{bmatrix} \mu_1 & \mu_2 & \mu_3 & \mu_4 & \mu_5 & \mu_6 & \mu_7 & \mu_8 & \mu_9 & \mu_{10} & \mu_{11} & \mu_{12} & \mu_{13} & \mu_{14} & \mu_{15} & \mu_{16} & \mu_{17} \\ \mu_1 & \mu_2 & \mu_3 & \mu_4 & \mu_5 & \mu_6 & \mu_7 & \mu_8 & \mu_9 & \mu_{10} & \mu_{11} & \mu_{12} & \mu_{13} & \mu_{14} & \mu_{15} & \mu_{16} & \mu_{17} \\ \mu_1 & \mu_2 & \mu_3 & \mu_4 & \mu_5 & \mu_6 & \mu_7 & \mu_8 & \mu_9 & \mu_{10} & \mu_{11} & \mu_{12} & \mu_{13} & \mu_{14} & \mu_{15} & \mu_{16} & \mu_{17} \\ \mu_1 & \mu_2 & \mu_3 & \mu_4 & \mu_5 & \mu_6 & \mu_7 & \mu_8 & \mu_9 & \mu_{10} & \mu_{11} & \mu_{12} & \mu_{13} & \mu_{14} & \mu_{15} & \mu_{16} & \mu_{17} \\ \mu_1 & \mu_2 & \mu_3 & \mu_4 & \mu_5 & \mu_6 & \mu_7 & \mu_8 & \mu_9 & \mu_{10} & \mu_{11} & \mu_{12} & \mu_{13} & \mu_{14} & \mu_{15} & \mu_{16} & \mu_{17} \end{bmatrix}$$

........(1)
VII. Model Solution

On writing equation (1) after applying algebra of logics as follows:

By using algebra of logics, we write equation (1) again as follows

\[ F(\mu_1, \mu_2, \ldots, \mu_{17}) = (\phi_1 \land \phi_2 \land \phi_3 \land \phi_4 \land \phi_5 \land \phi_6 \land \phi_7) \land \delta(\mu_1, \mu_2, \ldots, \mu_{17}) \]  
\[ \delta(\mu_1, \mu_2, \ldots, \mu_{17}) = \begin{vmatrix} \mu_1 \mu_2 \mu_3 \mu_4 \mu_5 \mu_6 \mu_7 \\ \mu_5 \mu_6 \mu_7 \mu_1 \mu_2 \mu_3 \mu_4 \\ \mu_7 \mu_1 \mu_2 \mu_3 \mu_4 \mu_5 \mu_6 \\ \mu_3 \mu_1 \mu_2 \mu_4 \mu_5 \mu_6 \mu_7 \\ \mu_2 \mu_1 \mu_3 \mu_4 \mu_5 \mu_6 \mu_7 \\ \mu_6 \mu_5 \mu_1 \mu_4 \mu_3 \mu_2 \mu_7 \\ \mu_1 \mu_5 \mu_6 \mu_7 \mu_2 \mu_3 \mu_4 \\ \mu_4 \mu_5 \mu_6 \mu_7 \mu_1 \mu_2 \mu_3 \\ \end{vmatrix} \]  
\[ \omega = \begin{vmatrix} M_1 \\ M_2 \\ M_3 \\ M_4 \\ M_5 \\ M_6 \\ \end{vmatrix} \]

Where

\[ \omega = \begin{vmatrix} \mu_1 \mu_2 \mu_3 \mu_4 \mu_5 \mu_6 \mu_7 \\ \mu_5 \mu_6 \mu_7 \mu_1 \mu_2 \mu_3 \mu_4 \\ \mu_7 \mu_1 \mu_2 \mu_3 \mu_4 \mu_5 \mu_6 \\ \mu_3 \mu_1 \mu_2 \mu_4 \mu_5 \mu_6 \mu_7 \\ \mu_2 \mu_1 \mu_3 \mu_4 \mu_5 \mu_6 \mu_7 \\ \mu_6 \mu_5 \mu_1 \mu_4 \mu_3 \mu_2 \mu_7 \\ \mu_1 \mu_5 \mu_6 \mu_7 \mu_2 \mu_3 \mu_4 \\ \mu_4 \mu_5 \mu_6 \mu_7 \mu_1 \mu_2 \mu_3 \\ \end{vmatrix} \]

By using the method of orthogonalization we write algorithm (3) as

\[ M_1' \quad M_1' \quad M_2' \quad M_3' \quad M_4' \quad M_5' \quad M_6' \]

\[ \delta(\mu_1, \mu_2, \ldots, \mu_{17}) = \begin{vmatrix} \mu_4 \mu_5 \mu_6 \mu_7 \\ \mu_1 \mu_2 \mu_3 \mu_4 \\ \mu_5 \mu_6 \mu_7 \mu_1 \\ \mu_3 \mu_4 \mu_5 \mu_6 \\ \mu_2 \mu_3 \mu_4 \mu_5 \\ \mu_6 \mu_7 \mu_1 \mu_2 \\ \mu_1 \mu_2 \mu_3 \mu_4 \\ \mu_5 \mu_6 \mu_7 \mu_1 \\ \end{vmatrix} \]

VIII. Result and Discussion

If the reliability be G and the unreliability be H then the reliability of the whole system is given by:

CASE I: If G is each Component Reliability then Algorithm (4) given as

\[ G(x) = G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \quad + G^0 \]

CASE II: When the Failure Rate Follows Weibull Time Distribution.

If failure rate is \( Y_i \) for section state \( x_i \), for all \( i = 1, 2, \ldots, 17 \) then chocolate manufacturing plant reliability at an instant \( x \) is given by:

When \( u = 0.01 \) and \( x = 0.1, 2, 3, 4, 5, \ldots \) numerical results obtained to study effect of various reliability parameters for the steady state of the system. If the parameters like failure rate and repair rate are altered the reliability of the system is affected.

\[ G_{\text{in}}(x) = \sum_{i=1}^{17} \sum_{j=1}^{17} \exp(-\theta_i x_j) \sum_{k=1}^{17} \exp(-\phi_j x_k) \]

\[ G_{\text{out}}(x) = \exp(-4x) + \exp(-5x) + \exp(-6x) + \exp(-7x) + \exp(-8x) + \exp(-9x) + \exp(-10x) + \exp(-11x) + \exp(-12x) + \exp(-13x) + \exp(-14x) + \exp(-15x) + \exp(-16x) + \exp(-17x) + \exp(-18x) + \exp(-19x) + \exp(-20x) \]

where, s is +ve and \( \phi \) and \( \theta \) are as follows:

\[ \omega_1 = Y_{12} Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]
\[ \omega_2 = Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]
\[ \omega_3 = Y_{14} Y_{15} Y_{16} Y_{17} \]
\[ \omega_4 = Y_{15} Y_{16} Y_{17} \]

\[ \omega_5 = Y_{12} Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_6 = Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_7 = Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_8 = Y_{15} Y_{16} Y_{17} \]

\[ \omega_9 = Y_{12} Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{10} = Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{11} = Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{12} = Y_{15} Y_{16} Y_{17} \]

\[ \omega_{13} = Y_{12} Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{14} = Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{15} = Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{16} = Y_{15} Y_{16} Y_{17} \]

\[ \omega_{17} = Y_{16} Y_{17} \]

\[ \omega_{18} = Y_{17} Y_{18} Y_{19} Y_{20} Y_{21} Y_{22} \]

\[ \omega_{19} = Y_{12} Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{20} = Y_{13} Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{21} = Y_{14} Y_{15} Y_{16} Y_{17} \]

\[ \omega_{22} = Y_{15} Y_{16} Y_{17} \]
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\[ \phi_{30} = \sum \gamma_8 \gamma_9 \gamma_{10} \gamma_{11} \gamma_{12} \gamma_{13} \gamma_{14} \gamma_{15} \gamma_{16} \]

\[ \phi_{31} = \sum \gamma_8 \gamma_9 \gamma_{10} \gamma_{11} \gamma_{12} \gamma_{13} \gamma_{14} \gamma_{15} \gamma_{16} \gamma_{17} \]

Table-I: Reliability under Weibull distribution

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<tr>
<th>U</th>
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<th>G_{SW}(x)</th>
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<tr>
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</tr>
<tr>
<td>0.01</td>
<td>7</td>
<td>0.8072261</td>
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<tr>
<td>0.01</td>
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</tr>
<tr>
<td>0.01</td>
<td>9</td>
<td>0.7246362</td>
</tr>
</tbody>
</table>

CASE III: WHEN FAILURE RATE FOLLOWS EXPONENTIAL DISTRIBUTION.

At an instant ‘s’ the whole system reliability is expressed as

\[ G_{SE}(x) = \sum \exp(-\phi_i x) - \sum \exp(-\phi_j x) \]

\[ = \exp(-4ux) + 2\exp(-5ux) - \exp(-6ux) + \exp(-7ux) - 4\exp(-8ux) + 3\exp(-9ux) - \exp(-10ux) \]

\[ = e^{-4ux} + 2e^{-5ux} - e^{-6ux} + e^{-7ux} - 4e^{-8ux} + 3e^{-9ux} - e^{-10ux} \]

Table-II: Reliability under exponential distribution

<table>
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<th>U</th>
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</tr>
</thead>
<tbody>
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<tr>
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<td>7</td>
<td>0.9370933</td>
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<tr>
<td>0.01</td>
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</tr>
<tr>
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<td>0.9037716</td>
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</table>

Table-III: Comparison of reliability in exponential and Weibull distribution:

<table>
<thead>
<tr>
<th>x</th>
<th>G_{SW}(x)</th>
<th>G_{SE}(x)</th>
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<td>1</td>
</tr>
<tr>
<td>1</td>
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<td>9</td>
<td>0.7246362</td>
<td>0.9037716</td>
</tr>
</tbody>
</table>

The mean time to failure (M.T.T.F) is obtained as

\[ \text{M.T.T.F.} = \int_0^\infty G_{SE}(x) dx \]
SECTION II
NEURAL NETWORK APPROACHES FOR ANALYTICAL OF CHOCOLATE MANUFACTURING PLANT.

In figure 3 the working of chocolate manufacturing system is discussed. The accurate estimation of different reliability measures can help in decision making and change the future performance of the system. Design deficiencies unavoidable complexities may result in increasing unreliability of system. Failure rate has major significance in reliability analysis. For neural network approach, the failure rates and repair rates are taken as neural weights. Back propagation algorithm is used to determine the weights of neural network. The reliability is obtained by repeating the process of determining and adjusting the weights. Using Feed Forward algorithm, MATLAB program is developed to find various measures of reliability

**EQUATIONS**

The basic equations of neural network are represented in the following:

\[ Y_i = p_i(t+\Delta t) ; \text{ where } i = 1, 2, 3, \ldots, 20. \]

\[ Y_1 = \phi_{11}X_1 + \phi_{12}X_2 + \phi_{13}X_3 + \phi_{14}X_4 + \phi_{15}X_5 + \phi_{16}X_6 + \phi_{17}X_7 + \phi_{18}X_8 + \phi_{19}X_9 + \phi_{20}X_{20}, \]

\[ Y_2 = \phi_{21}X_1 + \phi_{22}X_2, \]

\[ Y_3 = \phi_{31}X_1 + \phi_{32}X_2, \]

\[ Y_4 = \phi_{41}X_1 + \phi_{42}X_2, \]

\[ Y_5 = \phi_{51}X_1 + \phi_{52}X_2, \]

\[ Y_6 = \phi_{61}X_1 + \phi_{62}X_2, \]

\[ Y_7 = \phi_{71}X_1 + \phi_{72}X_2, \]

\[ Y_8 = \phi_{81}X_1 + \phi_{82}X_2, \]

\[ Y_9 = \phi_{91}X_1 + \phi_{92}X_2 + \phi_{93}X_3 + \phi_{94}X_4 + \phi_{95}X_5 + \phi_{96}X_6 + \phi_{97}X_7 + \phi_{98}X_8 + \phi_{99}X_9 + \phi_{100}X_{10}, \]

\[ Y_{10} = \phi_{101}X_1 + \phi_{102}X_2 + \phi_{103}X_3 + \phi_{104}X_4 + \phi_{105}X_5 + \phi_{106}X_6 + \phi_{107}X_7 + \phi_{108}X_8 + \phi_{109}X_9 + \phi_{110}X_{11}, \]

\[ Y_{11} = \phi_{111}X_1 + \phi_{112}X_2 + \phi_{113}X_3 + \phi_{114}X_4 + \phi_{115}X_5 + \phi_{116}X_6 + \phi_{117}X_7 + \phi_{118}X_8 + \phi_{119}X_9 + \phi_{120}X_{12}, \]

\[ Y_{12} = \phi_{121}X_1 + \phi_{122}X_2 + \phi_{123}X_3 + \phi_{124}X_4 + \phi_{125}X_5 + \phi_{126}X_6 + \phi_{127}X_7 + \phi_{128}X_8 + \phi_{129}X_9 + \phi_{130}X_{13}, \]

\[ Y_{13} = \phi_{131}X_1 + \phi_{132}X_2 + \phi_{133}X_3 + \phi_{134}X_4 + \phi_{135}X_5 + \phi_{136}X_6 + \phi_{137}X_7 + \phi_{138}X_8 + \phi_{139}X_9 + \phi_{140}X_{14}, \]

\[ Y_{14} = \phi_{141}X_1 + \phi_{142}X_2 + \phi_{143}X_3 + \phi_{144}X_4 + \phi_{145}X_5 + \phi_{146}X_6 + \phi_{147}X_7 + \phi_{148}X_8 + \phi_{149}X_9 + \phi_{150}X_{15}, \]

\[ Y_{15} = \phi_{151}X_1 + \phi_{152}X_2 + \phi_{153}X_3 + \phi_{154}X_4 + \phi_{155}X_5 + \phi_{156}X_6 + \phi_{157}X_7 + \phi_{158}X_8 + \phi_{159}X_9 + \phi_{160}X_{16}, \]

\[ Y_{16} = \phi_{161}X_1 + \phi_{162}X_2 + \phi_{163}X_3 + \phi_{164}X_4 + \phi_{165}X_5 + \phi_{166}X_6 + \phi_{167}X_7 + \phi_{168}X_8 + \phi_{169}X_9 + \phi_{170}X_{17}, \]

\[ Y_{17} = \phi_{171}X_1 + \phi_{172}X_2 + \phi_{173}X_3 + \phi_{174}X_4 + \phi_{175}X_5 + \phi_{176}X_6 + \phi_{177}X_7 + \phi_{178}X_8 + \phi_{179}X_9 + \phi_{180}X_{18}, \]

\[ Y_{18} = \phi_{181}X_1 + \phi_{182}X_2 + \phi_{183}X_3 + \phi_{184}X_4 + \phi_{185}X_5 + \phi_{186}X_6 + \phi_{187}X_7 + \phi_{188}X_8 + \phi_{189}X_9 + \phi_{190}X_{19}, \]

\[ Y_{19} = \phi_{191}X_1 + \phi_{192}X_2 + \phi_{193}X_3 + \phi_{194}X_4 + \phi_{195}X_5 + \phi_{196}X_6 + \phi_{197}X_7 + \phi_{198}X_8 + \phi_{199}X_9 + \phi_{200}X_{20}, \]

**IX. EXPERIMENTAL RESULTS**

The proposed method has been tested on the data obtained from chocolate manufacturing system.

System uptime (according to the state transition diagram):

\[ P_{\text{uptime}}(t) = Y_{18} + Y_{9} + Y_{14}. \]

Failure rate has major significance in reliability analysis. For neural network approach, the failure rates and repair rates are taken as neural weights. Back propagation algorithm is used to determine the weights of neural network. The reliability is obtained by repeating the process of determining and adjusting the weights. Using Feed Forward algorithm, MATLAB program is developed to find various measures of reliability

\[ P_{\text{uptime}}(t) = e^{-at} - \Lambda_{c1}/(a-b) \ e^{-at} + \Lambda_{c1}/(a-b) \ e^{bt}. \]

It is interesting to note that \( P_{\text{uptime}}(t) = 1. \) (tending to 1) If the number of iterations are more than better result can be obtained. This results shows that how reliability is affected when time diversifies. In addition to this we calculate cost analysis of the system with time using following equation.

Profit function \( G(t) = \int_0^t P_{\text{uptime}}(t) - C2t - C3. \)

Where, \( C1 = \) revenue cost, \( C2 = \) repair cost per unit time and \( C3 = \) establishment cost of system.

**Table – V: Comparative cost with respect to time**

<table>
<thead>
<tr>
<th>t</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
<td>0</td>
</tr>
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**Figure 4: time vs reliability**
Assessment of Reliability Factors in Chocolate Manufacturing Plant using Boolean Function Technique and Neural Networking.

X. CONCLUSIONS

In this paper to calculate reliability, we discussed two different approaches neural network approach and Boolean approach for chocolate manufacturing plant. Critical observations of the tables and respected graphs reveal that reliability of the system for finite interval of time is much higher, but after a sufficient long interval of time it is reduced; while mean time to system failure fails gradually. We considered the graph of reliability with time using two different techniques. System profit in long time shown in figure 5.which will be a great help to economist. To evaluate various reliability factors technique of Neural is very useful. Our Role to evaluate reliability using both techniques is just an little step to find out such important technological field. It is hoped that this contribution can use as a vital resource for contemporary time applications.

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