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# Mathematical Modeling and Analysis of Container Manufacturing Plant in Transient State

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**Abstract.** In the present work, time dependent availability of a mechanical system i.e., container manufacturing plant is estimated. Here, Mathematical modeling has been developed on the basis of Markov birth-death process using probabilistic approach. The first order governing equations thus formulated using the mnemonic rule is solved to estimate the availability of the system in the transient state. The failure rates and the repair rates of the subsystems are taken constant. Matrix method has been applied to calculate transient state availability of the system up to desired decimal places. The time dependent availability is shown with the help of graph and the parameter MTTF is obtained. Correlation and regression coefficients between time and availability have been computed to study the variation between time and availability. The results obtained in the present work are considered to be very useful for taking all maintenance decisions associated with container manufacturing plant.

***Keywords:*** *Availability, Correlation, Regression, Differential difference equation, Mathematical modeling, Mean time to failure and Mnemonic Rule.*

## 1. Introduction

The performance of process industries depends on the reliability, availability and maintainability of the system used, the operating environment, maintenance planning and control etc. As the complexity of process industries continues to increase, the chances of system failure become more critical. Therefore, RAM analysis is required to find the weak spots in the system so that proper maintenance planning and control can be done. Our purpose is to discuss in detail the availability calculations involved in manufacturing a container and also to stress the importance of estimating the reliability factors in such a system. The Container manufacturing plant comprises of three major parts (a) the main shell construction (b) end dish construction (c) fitting of end dishes. These three parts work in series and hence successful working of all is necessary. Since, (b) and (c) do not fail; the main shell construction is the most important. In this paper, the main shell construction system is studied. Taking constant failure and repair rates for each subsystem, the mathematical formulation is done using Markov analysis. Expressions for time dependent availability and MTTF are derived with the help of Matrix method using computer program. Using this method we can easily study the variation of availability with respect to time. The main objective of present work is to identify and understand the system to model their logical and functional structure, identify solution techniques of mathematical model, and to find the possibility of application for repairable equipments. The results are useful for reliability engineers and container manufacturers to determine best possible maintenance action.

## 2. Literature Survey

The development of reliability theory was accompanied by improvement in the probabilistic methods of study. The establishment of quantitative reliability factors and methods of measuring and calculating them marked the beginning of the scientific methods for the study of reliability. Mathematical methods to improve availability of a product in different process industries such as Dairy plant, Paper industry, Bread manufacturing plant has been applied by many researchers. Dhillon et al. (1981) have frequently used the markovian approach for the availability analysis, using exponential distribution for failure and repair times. Various authors have discussed wide degree of complexities for the assessment of availability, reliability and maintainability. Mostly these models are based on the Markovian approach, where the failure and repair rates are assumed to be constant. Kumar et al. (1988, 1989, 1990, and 1991) discussed the reliability and availability of Paper, Sugar and Fertilizer industry. They analyzed the designed and cost of a refining system in the sugar industry using supplementary variable technique. Dayal and Singh (1992) studied reliability analysis of a system in a fluctuating environment. Singh and Mahajan (1999) examined the reliability and long run availability of a Utensils Manufacturing Plant using Laplace transforms.

Castro and Cavalca (2003) presented an availability optimization problem of an engineering system assembled in series configuration which has redundancy of units and teams of maintenance as optimization parameters. Gupta et al. (2005) studied the behavior of Cement manufacturing plant. Singh and Goyal (2006) discussed availability in Bread manufacturing plant. Kiureghian and Ditlevson (2007) analysed the availability, reliability and downtime of system with repairable components. It has been observed that calculation of time dependent availability is very difficult in complex systems. Most of these authors use Laplace transform method, langrange's technique and Runge Kutta method to obtain the availability of the system. It is seen that at the higher value of some parameter Laplace inverse technique becomes so complex to calculate the steady state as well as time dependent availability. Similarly solving higher order integrals is very difficult in langrange's method. Therefore some alternative method is to be devised to entertain these problems. In the present work, we have developed the matrix method to solve differential equations in transient state. The Matrix Method provides an easy way to estimate the variation in system performance in terms of availability with respect to time and computer program is developed to calculate the time dependent availability. The time dependent availability of the container manufacturing plant is also shown with the help of graph. The concept of correlation and regression are also implied to study the relation of availability with time. By studying these tables we can find out which subsystem requires preventive maintenance to avoid any possible failures. Hence, results obtained in the present work are considered to be very useful for taking the best possible maintenance strategies.

## 3. Description of the System

The raw material (i.e., long steel plates) used for the construction of shell is supplied from steel plant. During the manufacturing process, all the steel sheets are cut in to different sizes in cutting yard by gas cutting machine. These sheets are taken to the hydraulic pressing machine to shape them before rolling. The rolling machines then shape the sheets in to required hollow cylindrical shape. The rolled cylinder is welded with long welding machines in order to form an open cylinder i.e. the main shell of the container. The Shell construction system is composed of the following subsystems:

a) Gas cutting machine (A) having only one unit subjected to major failure only.

b) Hydraulic pressing machine (B) consisting two units in parallel subjected to minor and major failures

c) Rolling machine (C) consisting three units in parallel subjected to minor and major failures.

d) Welding machine (D) having three units in parallel subjected to minor and major failures.

## 4. Assumptions and Notations

a) At any given time the system is either in operating state or in the failed state.

b) There are no simultaneous failures among the subsystems.

c) Switch over device is perfect.

d) Repairs and failures are taken as constant and are independent of each other.

e) Repaired systems are like new systems.

f) The subsystem Hydraulic pressing machine (B), rolling machine (C), and welding machine (D) fails only through reduced states.

g) Repair is carried out only when the subsystems are in reduced or failed state.

A, B, C, D: denote the good state of the system.

a, b, c, d: represents the failure states of the subsystem A, $\overline{B}$, $\overline{C}$ and $\overline{D}$ respectively.

$\lambda_i$ $(1 \le i \le 7)$ : represents failure rate of subsystems A, B, C, D $\overline{B}$, $\overline{C}$ and $\overline{D}$.

$\mu_i$ $(1 \le i \le 7)$ : represents repair rate of subsystems A, B, C, D $\overline{B}$, $\overline{C}$ and $\overline{D}$.

$P_i(t) = P(i,t)$ : denotes probability that the system is in i$^{th}$ state at time t. $(0 \le i \le 27)$.

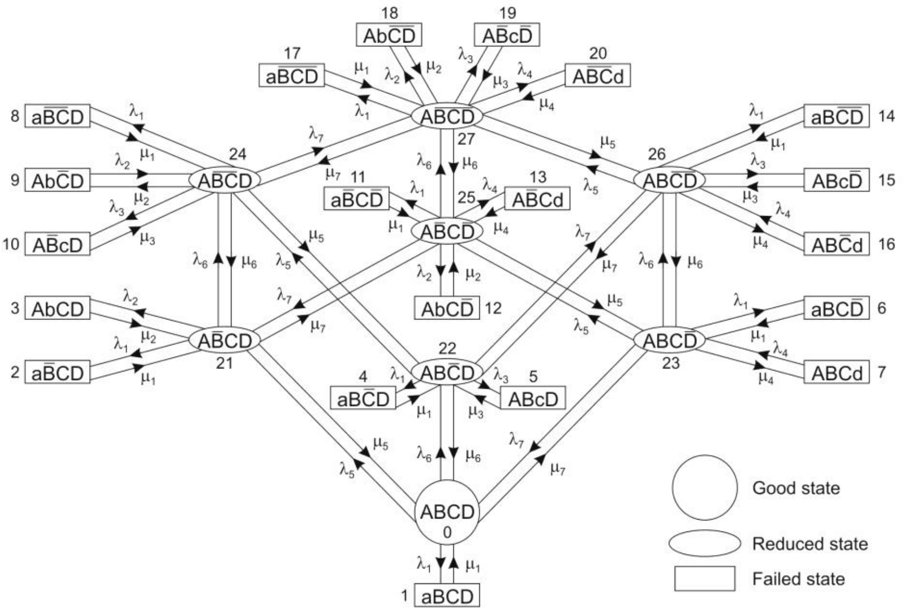
Indicates the system in operating condition

Indicates the system in reduced capacity state

Indicates the system in fail condition

## 5. Transition Diagram

Following the above notations and assumptions the transition diagram is as shown in Fig. (1).




**(Fig. 1)**

## 6. Mathematical Modeling of the System

The differential difference equations associated with the transition diagram are as follows:

$$P_0'(t) + A_1 P_0(t) = \mu_1 P_1(t) + \mu_5 P_{21}(t) + \mu_6 P_{22}(t) + \mu_7 P_{23}(t);$$

$$P_1'(t) + \mu_1 P_1(t) = \lambda_1 P_0(t);$$

$$P_{i+1}'(t) + \mu_i P_{i+1}(t) = \lambda_i P_{21}(t);\ i = 1, 2;$$

$$P_4'(t) + \mu_1 P_4(t) = \lambda_1 P_{22}(t);$$

$$P_5'(t) + \mu_3 P_5(t) = \lambda_3 P_{22}(t);$$

$$P_6'(t) + \mu_1 P_6(t) = \lambda_1 P_{23}(t);$$

$$P_7'(t) + \mu_4 P_7(t) = \lambda_4 P_{23}(t);$$

$$P_{i+7}'(t) + \mu_i P_{i+7}(t) = \lambda_i P_{24}(t);\ i = 1, 2, 3;$$

$$P_{i+10}'(t) + \mu_i P_{i+10}(t) = \lambda_i P_{25}(t);\ i = 1, 2;$$

$$P_{13}'(t) + \mu_4 P_{13}(t) = \lambda_4 P_{25}(t);$$

$$P_{14}'(t) + \mu_1 P_{14}(t) = \lambda_1 P_{26}(t);$$

$$P_{i+12}'(t) + \mu_i P_{i+12}(t) = \lambda_i P_{26}(t);\ i = 3, 4;$$

$$P_{i+16}'(t) + \mu_i P_{i+16}(t) = \lambda_i P_{27}(t);\ i = 1, 2, 3, 4;$$

$$P_{21}'(t) + A_2 P_{21}(t) = \mu_1 P_2(t) + \mu_2 P_3(t) + \mu_6 P_{24}(t) + \mu_7 P_{25}(t) + \lambda_5 P_0(t);$$

$$P_{22}'(t) + A_3 P_{22}(t) = \mu_1 P_4(t) + \mu_3 P_5(t) + \mu_5 P_{24}(t) + \mu_7 P_{26}(t) + \lambda_6 P_0(t);$$

$$P_{23}'(t) + A_4 P_{23}(t) = \mu_1 P_6(t) + \mu_4 P_7(t) + \mu_6 P_{26}(t) + \mu_5 P_{25}(t) + \lambda_7 P_0(t);$$

$$P_{24}'(t) + A_5 P_{24}(t) = \mu_1 P_8(t) + \mu_2 P_9(t) + \mu_3 P_{10}(t) + \mu_7 P_{27}(t) + \lambda_5 P_{22}(t) + \lambda_6 P_{21}(t);$$

$$P_{25}'(t) + A_6 P_{25}(t) = \mu_1 P_{11}(t) + \mu_2 P_{12}(t) + \mu_4 P_{13}(t) + \mu_6 P_{27}(t) + \lambda_7 P_{21}(t) + \lambda_5 P_{23}(t);$$

$$P_{26}'(t) + A_7 P_{26}(t) = \mu_1 P_{14}(t) + \mu_3 P_{15}(t) + \mu_4 P_{16}(t) + \mu_5 P_{27}(t) + \lambda_6 P_{23}(t) + \lambda_7 P_{22}(t);$$

$$P_{27}'(t) + A_8 P_{27}(t) = \sum_{i=1}^{4} \mu_i P_{16+i}(t) + \lambda_5 P_{26}(t) + \lambda_6 P_{25}(t) + \lambda_7 P_{24}(t);$$

where $A_1 = \lambda_1 + \sum_{5}^{7} \lambda_i;\ A_2 = \lambda_1 + \lambda_2 + \lambda_6 + \lambda_7 + \mu_5;$

$$A_3 = \lambda_1 + \lambda_3 + \lambda_5 + \lambda_7 + \mu_6;\ A_4 = \lambda_1 + \lambda_4 + \lambda_5 + \lambda_6 + \mu_7;$$

$$A_5 = \sum_{1}^{3} \lambda_i + \lambda_7 + \mu_5 + \mu_6;\ A_6 = \lambda_1 + \lambda_2 + \lambda_4 + \lambda_6 + \mu_5 + \mu_7;$$

$$A_7 = \lambda_1 + \sum_{3}^{5} \lambda_i + \mu_6 + \mu_7;\ A_8 = \sum_{1}^{4} \lambda_i + \sum_{5}^{7} \mu_i;$$

with initial conditions $P_0(t) = 1,$ otherwise zero.

**Matrix A =**

$$
\left(\begin{array}{cccccccccccccccccccccccccccc}
-A_1 & \mu_1 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0 & \mu_5 & \mu_6 & \mu_7 & 0&0&0&0 \\
\lambda_1 & -\mu_1 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0 \\
0&0 & -\mu_1 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0&0 & \lambda_1 & 0&0&0&0&0& 0 \\
0&0&0 & -\mu_2 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0 & \lambda_2 & 0&0&0&0&0& 0 \\
0&0&0&0 & -\mu_1 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0 & \lambda_1 & 0&0&0&0&0 \\
0&0&0&0&0 & -\mu_3 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0 & \lambda_3 & 0&0&0&0&0 \\
0&0&0&0&0& 0 & -\mu_1 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0 & \lambda_1 & 0&0&0&0 \\
0&0&0&0&0& 0&0 & -\mu_4 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0 & \lambda_4 & 0&0&0&0 \\
0&0&0&0&0& 0&0&0 & -\mu_1 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0 & \lambda_1 & 0&0&0 \\
0&0&0&0&0& 0&0&0&0 & -\mu_2 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0 & \lambda_2 & 0&0&0 \\
0&0&0&0&0& 0&0&0&0&0 & -\mu_3 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0 & \lambda_3 & 0&0&0 \\
0&0&0&0&0& 0&0&0&0&0& 0 & -\mu_1 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0 & \lambda_1 & 0&0 \\
0&0&0&0&0& 0&0&0&0&0& 0&0 & -\mu_2 & 0&0&0&0&0& 0&0&0&0&0& 0&0 & \lambda_2 & 0&0 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0 & -\mu_4 & 0&0&0&0&0& 0&0&0&0&0& 0 & \lambda_4 & 0&0 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0 & -\mu_1 & 0&0&0&0&0& 0&0&0&0&0& 0 & \lambda_1 & 0 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0 & -\mu_3 & 0&0&0&0&0& 0&0&0&0&0 & \lambda_3 & 0 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0 & -\mu_4 & 0&0&0&0&0& 0&0&0&0 & \lambda_4 & 0 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0 & -\mu_1 & 0&0&0&0&0& 0&0&0&0 & \lambda_1 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0&0 & -\mu_2 & 0&0&0&0&0& 0&0&0 & \lambda_2 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0 & -\mu_3 & 0&0&0&0&0& 0&0 & \lambda_3 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0 & -\mu_4 & 0&0&0&0&0& 0 & \lambda_4 \\
\lambda_5 & 0 & \mu_1 & \mu_2 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0 & -A_2 & 0 & 0 & \mu_6 & \mu_7 & 0 & 0 \\
\lambda_6 & 0 & 0 & 0 & \mu_1 & \mu_3 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0 & -A_3 & 0 & \mu_5 & 0 & \mu_7 & 0 \\
\lambda_7 & 0&0&0&0&0 & \mu_1 & \mu_4 & 0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0 & -A_4 & 0 & \mu_5 & \mu_6 & 0 \\
0&0&0&0&0& 0&0&0 & \mu_1 & \mu_2 & \mu_3 & 0&0&0&0&0& 0&0&0&0&0 & \lambda_6 & \lambda_5 & 0 & -A_5 & 0 & 0 & \mu_7 \\
0&0&0&0&0& 0&0&0&0&0& 0 & \mu_1 & \mu_2 & \mu_4 & 0&0&0&0&0& 0&0 & \lambda_7 & 0 & \lambda_5 & 0 & -A_6 & 0 & \mu_6 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0 & \mu_1 & \mu_3 & \mu_4 & 0&0&0&0&0 & \lambda_7 & \lambda_6 & 0 & 0 & -A_7 & \mu_5 \\
0&0&0&0&0& 0&0&0&0&0& 0&0&0&0&0& 0&0 & \mu_1 & \mu_2 & \mu_3 & \mu_4 & 0 & 0 & 0 & \lambda_7 & \lambda_6 & \lambda_5 & -A_8
\end{array}\right)
$$

## 7. Availability Analysis

The availability of the system is obtained by solving the matrix differential difference equations $(\theta I - A)\ \bar{P}_i(t) = O$, where $\theta \equiv d/dt$, O is the null matrix, A is the matrix of the coefficients of the probability states $p_i(t)$ and I or $I_n$ is the identity matrix of order n.

The equations reduce to $C^{-1}(\theta I - D)\ \bar{P}_i(t) = O$, where C is the matrix such that $C^{-1}AC = D$, and $D = (d_1, d_2, \ldots, d_n)$ is the matrix of eigen values of A.

The availability of the system is sum of the availabilities of working subsystems.

$$Av(t) = P_0(t) + P_{21}(t) + P_{22}(t) + P_{23}(t) + P_{24}(t)\ ) + P_{25}(t) + P_{26}(t) + P_{27}(t)$$

$$= 1 + (a_{11} + a_{21} + a_{31} + a_{41})\ t + (b_{11} + b_{21} + b_{31} + b_{41})t^2/2! + \ldots$$

The entries $a_{ij}$, $b_{ij}$ etc. are respective entries in A, $B = A\ \bar{P}_i(0)$, $C = AB = A^2\ \bar{P}_i(0)$ so on.

**Availability of the main shell construction system at time t is**,

$$Av(t) = P_0(t) + P_{21}(t) + P_{22}(t) + P_{23}(t) + P_{24}(t) + P_{25}(t) + P_{26}(t) + P_{27}(t)$$

$$= 1 - 0.060000t + 0.001125t^2 - 0.0000096t^3 + \ldots$$

The availability of the system at t = 10 is **0.942193**

**Mean Time to Failure (Mttf):** The MTTF of the system for these failure and repair rates is obtained by integrating the availability function of the system.

$$\text{MTTF} = 1 - 0.060000\frac{t^2}{2} + 0.001125\frac{t^3}{3} - 0.0000096\frac{t^4}{4} + \ldots$$

The graph of time dependent availability is as shown in Fig.(2).

**The table of availability at different time intervals:**

**(Table -1)**

| | | | | | |
|---|---|---|---|---|---|
| Time | 10 | 20 | 30 | 40 | 50 |
| Availability | 0.942193 | 0.888555 | 0.838777 | 0.792573 | 0.749677 |
| Time | 60 | 70 | 80 | 90 | 100 |
| Availability | 0.709846 | 0.672853 | 0.638487 | 0.606554 | 0.576875 |
| Time | 110 | 120 | 130 | 140 | 150 |
| Availability | 0.549282 | 0.523621 | 0.499751 | 0.477538 | 0.456861 |

(TIME DEPENDENT AVAILABILITY GRAPH)

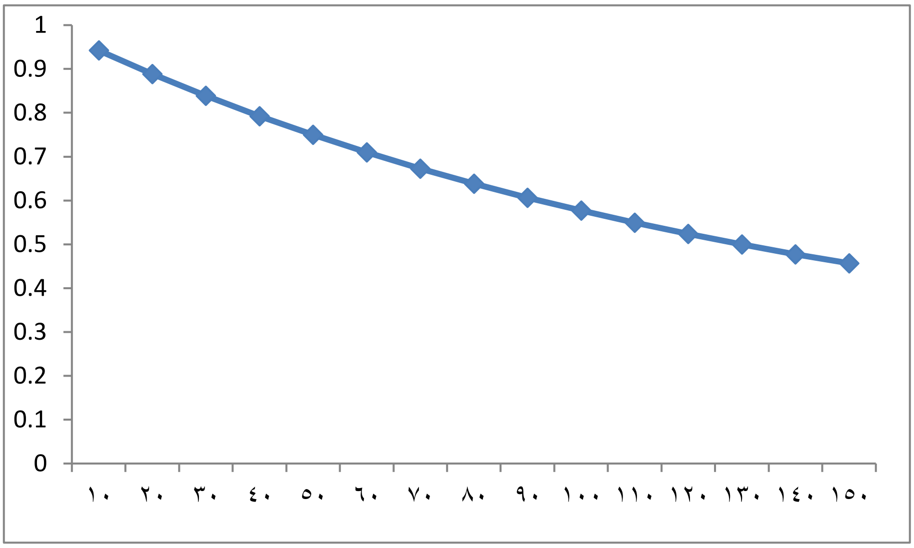



**Fig. (2).**

**The Program used**: Take failure rates and Repair rates as:

$\lambda_1 = 0.0015, \lambda_2 = 0.002, \lambda_3 = \lambda_4 = \lambda_5 = 0.001,$

$\lambda_6 = \lambda_7 = 0.0025, \mu_1 = 0.001, \mu_2 = \mu_3 = \mu_4 = 0.02,$

$\mu_5 = \mu_6 = 0.015, \mu_7 = 0.03$

```
#include<stdio.h>
```

```
#include<conio.h>
void main()
{
float a1[28][28],b[28][28],c[28][28],d[28][28],e[28][28],f[28][28];
float g[28][28],h[28][28],o[28][28],p[28][28],q[28][28],r[28][28];
float x1,x2,x3,x4,x5,x6,x7,x8,x9,x10,x11,x12,x;
int i,j,k,l,n=12,m=12,t=10;
float a[28][28]={-.0075,.001,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.015,.015,.03,0,0,0,0,
.0015,-.001,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,-.001,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.0015,0,0,0,0,0,0,
0,0,0,-.02,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.002,0,0,0,0,0,0,
0,0,0,0,-.001,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.0015,0,0,0,0,0,
0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.001,0,0,0,0,0,
0,0,0,0,0,0,-.001,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.0015,0,0,0,0,
0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.001,0,0,0,0,
0,0,0,0,0,0,0,0,-.001,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.0015,0,0,0,
0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.002,0,0,0,
0,0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,0,0,0,0,0,.001,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,-.001,0,0,0,0,0,0,0,0,0,0,0,0,0,.0015,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,0,0,0,0,.002,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,0,0,0,.001,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.001,0,0,0,0,0,0,0,0,0,0,0,.0015,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,0,0,.001,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,0,.001,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.001,0,0,0,0,0,0,0,0,0,.0015,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,0,.002,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,0,.001,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.02,0,0,0,0,0,0,.001,
.001,0,.001,.02,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.0235,0,0,.015,.03,0,0,
.0025,0,0,0,.001,.02,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.0210,0,.015,0,.03,0,
.0025,0,0,0,0,0,.001,.02,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-.0360,0,.015,.015,0,
0,0,0,0,0,0,0,0,.001,.02,.02,0,0,0,0,0,0,0,0,0,0,.0025,.001,0,-.0370,0,0,.03,
0,0,0,0,0,0,0,0,0,0,0,.001,.02,.02,0,0,0,0,0,0,0,.0025,0,.001,0,-.0520,0,.015,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,.001,.02,.02,0,0,0,0,0,.0025,.0025,0,0,-.0360,.015,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,.001,.02,.02,.02,0,0,0,.0025,.0025,.001,-.065};
clrscr();
for(i=0;i<m;i++)
```

```
{
for(j=0;j<n;j++)
{
b[i][j]=a[i][j];
}
}
for(i=0;i<m;i++)
{
for(j=0;j<l;j++)
{
c[i][j]=0;
for(l=0;l<m;l++)
c[i][j]=(((a[i][l]*b[l][j])*t)/2)+c[i][j];
}
}
```

///// The process of multiplication of matrices goes on depending upon the acceptance of the computer, to get more accuracy.

```
x1=((a[0][0]+a[1][0]+a[2][0]+a[3][0])*t);
printf("\n A11=%f",x1);
x2=((c[0][0]+c[1][0]+c[2][0]+c[3][0])*t);
printf("\n\n C11=%f",x2);
x3=((d[0][0]+d[1][0]+d[2][0]+d[3][0])*t);
printf("\n\n D11=%f",x3);
x4=((e[0][0]+e[1][0]+e[2][0]+e[3][0])*t);
printf("\n\n E11=%f",x4);
x5=((f[0][0]+f[1][0]+f[2][0]+f[3][0])*t);
printf("\n\n F11=%f",x5);
x6=((g[0][0]+g[1][0]+g[2][0]+g[3][0])*t);
printf("\n\n G11=%f",x6);
x7=((h[0][0]+h[1][0]+h[2][0]+h[3][0])*t);
printf("\n\n H11=%f",x7);
x8=((o[0][0]+o[1][0]+o[2][0]+o[3][0])*t);
printf("\n\n O11=%f",x8);
x9=((p[0][0]+p[1][0]+p[2][0]+p[3][0])*t);
printf("\n\n P11=%f",x9);
x10=((q[0][0]+r[1][0]+q[2][0]+q[3][0])*t);
printf("\n\n Q11=%f",x10);
```

```
x11=((r[0][0]+r[1][0]+r[2][0]+r[3][0])*t);
printf("\n\n R11=%f",x11);
printf("f(t)=\n\n\n1+%f+%f+%f+%f+%f+%f+%f+%f+%f+%f+%f\n",x1,x2,x3,x4,x5,x6,x7,x8,x9,x10,x11);
x=1+x1+x2+x3+x4+x5+x6+x7+x8+x9+x10+x11;
printf("\n\n x=%f",x);
getch();
}
```

## 8. Correlation Analysis

With the help of Correlation Analysis, the relationship between time and availability of main shell construction system is determined. Take x as time and y as availability.

| x | y | $X=x-\bar{x}$ | $Y=y-\bar{y}$ | $X^2$ | $Y^2$ | XY |
|---|---|---|---|---|---|---|
| 10 | 0.942193 | -40 | 0.200554 | 1600 | 0.04022 | -8.02216 |
| 20 | 0.888555 | -30 | 0.146916 | 900 | 0.02158 | -4.4074 |
| 30 | 0.838777 | -20 | 0.097138 | 400 | 0.00943 | -1.44276 |
| 40 | 0.792573 | -10 | 0.050934 | 100 | 0.00259 | -0.50934 |
| 50 | 0.749677 | 0 | 0.008038 | 0 | 0.000064 | 0 |
| 60 | 0.709846 | 10 | -0.03179 | 100 | 0.0010101 | -0.31793 |
| 70 | 0.672853 | 20 | -0.06878 | 400 | 0.004731 | -1.3757 |
| 80 | 0.638487 | 30 | -0.10315 | 900 | 0.01064 | -3.094 |
| 90 | 0.606554 | 40 | -0.13508 | 1600 | 0.01824 | -5.4034 |
| 100 | 0.576875 | 50 | -0.16476 | 2500 | 0.02714 | -8.2382 |
| $\sum x = 550$ | $\sum y = 7.41$ | | | $\sum X^2 = 8500$ | $\sum Y^2 = 0.135$ | $\sum XY=-32.$ |

Calculating coefficient of Correlation (r) from the above data:

$$r = \frac{\sum XY}{\sqrt{\sum X^2 . \sum Y^2}} = -0.966$$

Result: The value of correlation coefficient shows that time and availability are negatively correlated to each other.

## 9. Regression Analysis

With the help of regression analysis, the nature and strength of a relationship between time and availability of main shell construction system has been studied. We have developed an estimating equations that is, mathematical formulas that relates the time to the availability of main shell construction system. Take x as time and y as availability.

| X | y | xy | $x^2$ | $y^2$ |
|---|---|---|---|---|
| 10 | 0.942193 | 9.42193 | 100 | 0.88772 |
| 20 | 0.888555 | 17.7711 | 400 | 0.78952 |
| 30 | 0.838777 | 25.16331 | 900 | 0.70354 |
| 40 | 0.792573 | 31.70292 | 1600 | 0.62817 |
| 50 | 0.749677 | 37.48385 | 2500 | 0.56201 |
| 60 | 0.709846 | 42.59076 | 3600 | 0.50388 |
| 70 | 0.672853 | 47.09971 | 4900 | 0.45273 |
| 80 | 0.638487 | 51.07896 | 6400 | 0.42960 |
| 90 | 0.606554 | 54.58986 | 8100 | 0.36790 |
| 100 | 0.576875 | 57.6875 | 10000 | 0.33278 |
| | | $\sum xy=374.58$ | $\sum x^2=38500$ | $\sum y^2=5.657$ |

Calculating regression coefficients $b_{yx} = -0.00403, b_{xy} = -211.367$

Regression line of y on x:

$$(y-\bar{y}) = b_{yx}(x-\bar{x})$$

Putting the values, we get

$$y= -0.00403x + 0.963289 \quad .......(1)$$

Regression line of x on y:

$$(x-\bar{x}) = b_{xy}(y-\bar{y})$$

Putting the values, we get

$$x = -211.367y + 211.7580 \quad ........(2)$$

Equation (1) and (2) are estimating equations.

**Result:** Using the estimating equations, we can predict the availability on different intervals of time.

## 10. Discussion

The development of science and technology has a great impact on the modern society. The needs of modern society are increasing day by day. New industries are coming in order to meet the ever increasing demands of society. The complexities of industrial systems as well as their products are increasing day by day. The probability of performing definite tasks is determined by the availability of the system.

Better understanding of failures, improved manufacturing techniques, careful planning and designing of new systems and proper selection of subsystems are some of the measures by which availability can be improved. Availability provides necessary criteria by which alternate design policies can be improved and judged and help the manager or reliability engineer to select the one which best satisfies the objectives. The factors that mainly contribute to the availability are:

- The component failure process
- The system structure
- The maintainability and its policies
- The states in which the system is defined as success.

## 11. Conclusion

In this paper, we studied the main shell construction system. We found the availability in transient state and solved the differential difference equation with the help of matrix method using Computer program. The scope of this study is to review reliability, availability and maintainability (RAM) analysis in the container manufacturing plant and aims to identify the critical points of the production system that should be improved by the operational performance and the maintenance effectiveness. The present paper can help in increasing the quality and production of container manufacturing plant. The proposed method can be applied to complex systems that include a large system of differential equations. Using this method, we can easily study the variation of reliability with respect to time. Table (1) and figure (2) shows the variation of availability with respect to time which shows that as time increases, availability decreases. The same method can be applied in other industries so that the management can benefited from the same. Regression and Correlation analysis is done to determine both the nature and the strength of a relationship between time and availability. If the availability of main shell construction is denoted by $Av_1$ and the availability of end dish construction system and end dish fitting system is $Av_2$ and $Av_3$, respectively then the overall availability of the container manufacturing system is $A(v) = Av_1 \times Av_2 \times Av_3$.

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