DECISION SUPPORT SYSTEM OF A TAB MANUFACTURING PLANT

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Abstract: *This paper discusses a decision support system for a Tab manufacturing plant. Tab manufacturing mainly consists of six subsystems working in series .Two subsystems namely Grinding machine, Electroplating machine are supported by stand-by units with perfect switch over devices and the remaining four subsystem are prone to failure. The mathematical model of Tab manufacturing plant has been developed using Markov birth – death Process. The differential equations has been developed on the basis of probabilistic approach using transition diagram which are further solved for steady state availability in order to develop the decision matrices which provide the various availability levels for different combinations of failure and repair rates of each subsystem..*

Key words*: Availability, Differential Equations, Markov process, Steady State,*

INTRODUCTION

Majority of the systems in the industries are repairable systems. The performance of these systems can influence the quality of product, the cost of business, the service to the customers, and thereby the profit of enterprises directly. Modern repairable systems tend to highly complex due to increase in complexity and automation of civil and military systems

So far as the production operations are concerned, steady state availability analysis is essential, again on account of increased complexity and cost of present day equipment. Also the markets are getting globalize and more competitive. Penalties for delayed deliveries have increased. Sometimes the orders are cancelled and defaulting units are not favored with orders. To overcome these types of problems, steady state availability analysis is necessary for performance studies in the area of discrete manufacturing systems. Many researcher discussed steady state analysis of manufacturing plant by using different approaches. Law[23] used simulation modeling ,Dallery and Gershwin[24] discussed Markov chain models, Buzacott and Yao [25], Buzacott and Yao [26], Kouvelis and Tirupati [27] used queues and queuing network models , Viswanadham and Narahari[28],Al-Jaar and Desrochers [29] used stochastic Petri net models, Tewari,Kumar ,Kajal and Khanduja [16] used markov models for steady state analysis of manufacturing plant. Steady-state analysis deals mainly with customer average measures or time average measures. Performance measures such as steady-state waiting time belong to the first category whereas measures such as steady-state number of jobs in system are time average measures. Major results in queueing theory, such as Burke's result [30] , Little's law [31], Jackson's theorem [35], product form of closed queueing networks [32], the BCMP formulation [33], and the arrival theorem [34] are all concerned with steady-state analysis. This paper also deals with the steady state analysis of manufacturing plant namely Tab manufacturing. Which mainly consists of six subsystems working in series .Two subsystems namely Grinding machine, Electroplating machine are supported by stand-by units with perfect switch over devices and the remaining four subsystem are prone to failure. The mathematical modeling is done by using Markov birth – death Process and differential equations has been developed on the basis of probabilistic approach using transition diagram and solved for steady state. In this paper a decision support system is also developed which helps in determining the optimal maintenance strategy, which will ensure the maximum availability of the Tab manufacturing plant.

LITERATURE SURVEY

Recently, many researchers have discussed the reliability of different process industries using different techniques. Malik[2]discussed the maintenance scheduling for equipment, as appropriate maintenance of equipment is required to avoid loss of production and frequent preventive maintenance is costly. Singh, Kumar and Pandey [3, 5]discussed the reliability and availability of Fertilizer and Sugar industry .Shen [4] showed that reliability increases by adding standby unit at component and system level. Viswanadham [21], Buzacott and Shantikumar [22]discussed steady state analysis of manufacturing system. Singh,J and Kumar ,D [1,6] discussed the availability analysis of manufacturing plant.Michelson [7] discussed the use of reliability technology in process industry. Singh and Mahajan [8] examined the reliability and long run availability of a

Utensils Manufacturing Plant using Laplace transforms. Günes and Deveci[9] have studied the reliability of service systems and its application in student office and Habchi[10] discussed and improved the method of reliability assessment for suspended test and Jain[11]discussed N-Policy for redundant repairable system with additional repairman. Gupta, Lal, Sharma and Singh [12]discussed the reliability, long term availability and MTBF of cement industry with the help of Runga – Kutta method. Kiureghian and Ditlevson [13] analyzed the availability, reliability & downtime of system with repairable components. Kumar,Sigh,Sharma[15] discussed the of availability an automobile system namely "scooty". Tewari,Kumar ,Kajal ,Khanduja [16] discussed the availability of a Crystallization unit of a sugar plant. Garg,Kumar,Sigh [17]discussed the availability of cattle feed plant using matrix method. Panagiotis[18] had Classified and calculated primary failure modes in bread production line. Garg,Kumar,Sigh [19]discussed the availability of cattle feed plant using matrix method. Panagiotis Tsarouhas, Ioannis Arvanitoyannis, Theodoros and Varzakas[20]discussed reliability and maintainability analysis of cheese (feta) production line in a Greek medium-size.This paper analyze the Tab manufacturing plant for its steady state behavior.

SYSTEM DISCRIPTION

Six subsystems namely casting machine, forging machine, grinding machine, polishing machine, electroplating machine, assembling machine are used in the tab manufacturing plant. Initially the Casting machine is used to mould the raw material into the rough shape of the tab as per design, and then with the help of Forging machine necessary holes are done. After the forging, grinding of the component is done for smoothening the surface of the component by Grinding Machine. After this process polishing machine is used for the purpose of shining the component. Further electroplating is done to make the coating of silver colour on the components of tab with the help of Electroplating machine. Finally assembling process is done for assembling all the components of tab with the Assembling Machine.

The Tab manufacturing consists of the following six main subsystems:

I. Casting machine (A) consists of one unit. The system fails when this subsystem fails.
II. Forging machine (B) consists of one unit. The system fails when this subsystem fails.
III. Griding machine (C) consists of consists of two units, one working and the other is in cold standby. The cold standby unit is of lower capacity. The system works on standby unit in reduced capacity. Complete failure occurs when both units fail.
IV. Polishing machine (D) consists of one unit. The system fails when this subsystem fails.
V. Electroplating machine (E) consists of two units, one working and the other is in cold standby. The cold standby unit is of lower capacity. The system works on standby unit in reduced capacity. Complete failure occurs when both units fail
VI. Assembling machine (F), consists of one unit. It is subjected to major failure only.

ASSUMPTIONS AND NOTATIONS

I. Repair rates and failure rates are negative exponential and independent of each other.
II. Not more than one failure occurs at a time.
III. A repaired unit is, performance wise, as good as new.
IV. The subsystems C and E fail through reduced states.
V. Switch-over devices are perfect.
VI. Standby units are of the same nature and capacity as the active units.

A, B, C, D, E, F : Capital letters are used for good states.

$\overline{C}, \overline{E}$: Denotes the reduced capacity states.

a, b, c, d, e, f : Denotes the respective failed states.

λ_i : Indicates the respective mean failure rates of Casting machine, Forging machine, Griding machine, Polishing machine, Electroplating machine, Assembling machine. i =1,2,3,4,5,6,7,8. i = 4 and 7 stands for failure rates of reduced states of C and E respectively.

μ_i : Indicates the respective repair rates of Casting machine, Forging machine, Griding machine ,Polishing machine, Electroplating machine, Assembling machine., i =1,2,3,4,5,6, 7,8. i = 4and 7 stands for repair rates of reduced states of C and E respectively.

$P_i(t)$: Probability that the system is in i[th] state at time t.

$P_i'(t)$: Derivative of probability function $P_i(t)$.

TRANSITION DIAGARAM

Based upon above assumptions and notations, Transition diagram(Fig. 1) is prepared which represent of the transition of system form one state to another

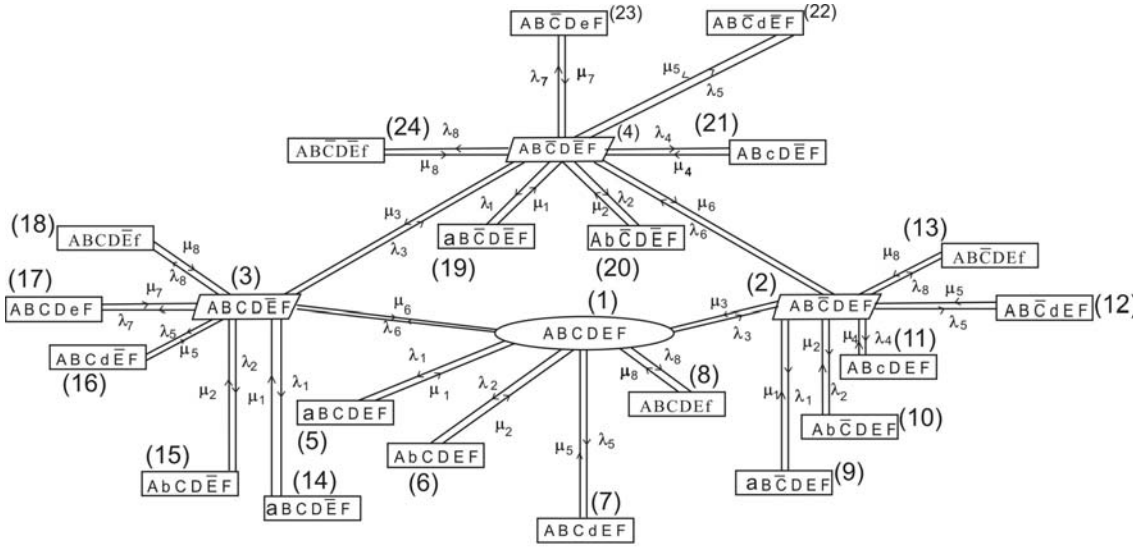

Figure 1: Transition Diagram of Tab Manufacturing Plant

MATHEMATICAL MODELING

Mathematical modeling of this system is done by applying markov-birth death process(srinath[36]) to each state one by one out of 24 sates of transition diagram.Probabilistic considerations give the following differential equations, associated with the transition diagram as given by figure 1.

$$p_1'(t) = a_1 p_1(t) + \mu_1 p_5(t) + \mu_2 p_6(t) + \mu_3 p_2(t) + \mu_5 p_7(t) + \mu_6 p_3(t) + \mu_8 p_8(t) \quad (1)$$

$$p_2'(t) = a_2 p_2(t) + \mu_1 p_9(t) + \mu_2 p_{10}(t) + \mu_4 p_{11}(t) + \mu_5 p_{12}(t) + \mu_6 p_4(t) + \mu_8 p_{13}(t) + \lambda_3 p_1(t) \quad (2)$$

$$p_3'(t) = a_3 p_3(t) + \mu_1 p_{14}(t) + \mu_2 p_{15}(t) + \mu_3 p_4(t) + \mu_5 p_{16}(t) + \mu_7 p_{17}(t) + \mu_8 p_{18}(t) + \lambda_6 p_1(t) \quad (3)$$

$$p_4'(t) = a_4 p_4(t) + \mu_1 p_{19}(t) + \mu_2 p_{20}(t) + \mu_4 p_{21}(t) + \mu_5 p_{22}(t) + \mu_7 p_{23}(t) + \mu_8 p_{24}(t) + \lambda_3 p_3(t) + \lambda_6 p_2(t) \quad (4)$$

Where

$$a_1 = -(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_5 + \lambda_6 + \lambda_8)$$

$$a_2 = -(\lambda_1 + \lambda_2 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_8 + \mu_3)$$

$$a_3 = -(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_5 + \lambda_7 + \lambda_8 + \mu_6)$$

$$a_4 = -(\lambda_1 + \lambda_2 + \lambda_4 + \lambda_5 + \lambda_7 + \lambda_8 + \mu_3 + \mu_6)$$

$$p_i'(t) + \mu_j p_i(t) = \lambda_j p_1(t) \quad i = 5, 6, 7, 8;\ j = 1, 2, 5, 8; \quad (5)$$

$$p_i'(t) + \mu_j p_i(t) = \lambda_j p_2(t) \quad i = 9, 10, 11, 12, 13;\ j = 1, 2, 4, 5, 8; \quad (6)$$

$$p_i'(t) + \mu_j p_i(t) = \lambda_j p_3(t) \quad i = 14, 15, 16, 17, 18;\ j = 1, 2, 5, 7, 8; \quad (7)$$

$$p_i'(t) + \mu_j p_i(t) = \lambda_j p_4(t) \quad i = 19, 20, 21, 22, 23, 24;\ j = 1, 2, 4, 5, 7, 8; \quad (8)$$

With initial conditions $P_1(0) = 1$, otherwise zero.

The Tab manufacturing plant is required to be available for long duration of time. So, the long run or steady state probability of the system is obtained by putting $d/dt = 0$ and $P_i(t) \to P_i$ as $t \to \infty$ in equations !1) to (8). The values of steady state probabilities are obtained in terms of P_1 as follows:

$p_2 = k_2 p_1$ $\quad p_3 = k_3 p_1$

$p_4 = k_4 p_1$ $\quad p_5 = c_1 p_1$

$p_6 = c_2 p_1$ $\quad p_7 = c_5 p_1$

$p_8 = c_8 p_1$ $\quad p_9 = c_1 k_2 p_1$

$p_{10} = c_2 k_2 p_1$ $\quad p_{11} = c_4 k_2 p_1$

$p_{12} = c_5 k_2 p_1$ $\quad p_{13} = c_8 k_2 p_1$

$p_{14} = c_1 k_3 p_1$ $\quad p_{15} = c_2 k_3 p_1$

$p_{16} = c_5 k_3 p_1$ $\quad p_{17} = c_7 k_3 p_1$

$p_{18} = c_8 k_3 p_1$ $\quad p_{19} = c_1 k_4 p_1$

$$p_{20} = c_2 k_4 p_1 \qquad p_{21} = c_4 k_4 p_1$$
$$p_{22} = c_5 k_4 p_1 \qquad p_{23} = c_7 k_4 p_1$$
$$p_{24} = c_8 k_4 p_1$$

Where

$c_1 = \lambda_i / \mu_i$ Where i=1, 2, 3, 4, 5, 6, 7, 8

And

Where

$$k_2 = \mu_6 a_{43} a_{31} + \lambda_3 / a_{22}$$
$$k_3 = a_{31} + a_{32} k_2$$
$$k_4 = a_{42} k_2 + a_{43} k_3$$

Where

$$a_{43} = \lambda_3 / \mu_3 + \mu_6$$
$$a_{42} = \lambda_6 / \mu_3 + \mu_6$$

And

$$a_{31} = \lambda_6 / a_{33}(\lambda_3 + \mu_6)$$
$$a_{32} = \mu_3 a_{42} / a_{33}(\lambda_3 + \mu_6)$$

Where

$$a_{33} = 1 - \left(\mu_3 a_{43} / \lambda_3 + \mu_6 \right)$$

And

$$a_{21} = (\mu_6 a_{43} a_{31} + \lambda_3) / a_{22}$$

Where

$$a_{22} = \lambda_6 + \mu_3 - (\mu_6 a_{43} a_{32} + \mu_6 a_{42})$$

The probability of full capacity working state (initial state), p_1 is determined by using normalizing condition i.e.

$$\sum_{i=1}^{24} p_i = 1$$

$$p_1(1 + k_2 + k_3 + k_4 + c_1 + c_2 + c_5 + c_8 + c_1 k_2 + c_2 k_2 + c_4 k_2 + c_5 k_2 + c_8 k_2 + c_1 k_3 + c_2 k_3 + c_5 k_3 + c_7 k_3 + c_8 k_3 + c_1 k_4 + c_2 k_4 + c_4 k_4 + c_5 k_4 + c_7 k_4 + c_8 k_4) = 1$$

$$p_1 * N = 1$$

$$P_1 = 1/N$$

Now, the steady state availability of the Tab manufacturing is given by

$A_v = p_1 + p_2 + p_3 + p_4$

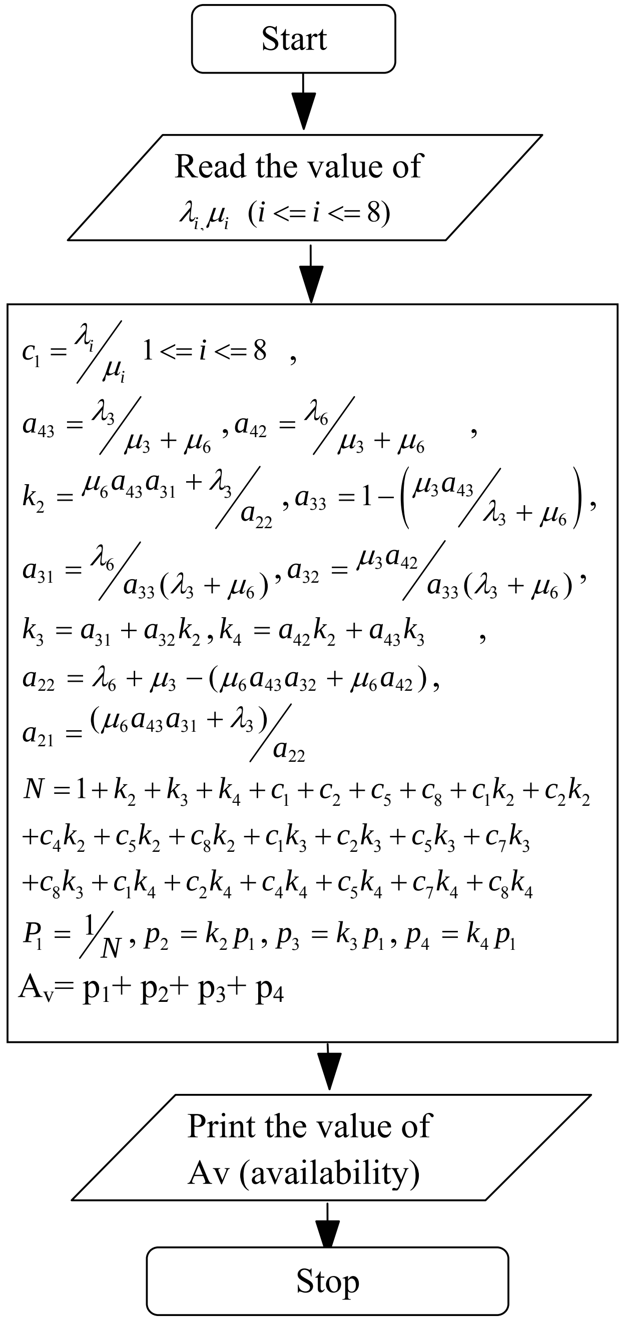

Figure 2: Computational flowchart for decision Support System

DECISION SUPPORT SYSTEM

The decision support system deals with the quantitative analysis of all the factors viz. maintenance strategies and states of nature which influence the maintenance decisions associated with the Tab manufacturing plant. These decision models are developed under the real decision making environment i.e. decision making under uncertainty (probabilistic model) for the purpose of performance evaluation. Such models are used to implement the proper maintenance decisions for a Tab manufacturing plant.

Figure 2 represents the computational algorithm to find the value of steady state availability for different combination of failure and repair rate. A C-program is developed which is as per flowchart for calculating the results. Table 1, 2 ,3,4,5 and 6 represent the decision matrices for various subsystems of a Tab manufacturing plant . These matrices simply reveal the various availability levels for different combinations of failure events and repair priorities. On the basis of decision support system developed, we may select possible combination (λ_i,μ_i.)i.e. optimal maintenance strategy. Table 1 i.e .decision matrix for the Casting machine subsystem, For some known values of failure/ repair rates of Forging machine, Griding machine, Polishing machine, Electroplating machine, Assembling machine, it reveals the effect of failure/ repair rates of Casting machine sub-system on the availability of Tab manufacturing plant . Similarly, it also explains the effect of failure/ repair rates of Forging machine, Griding machine, Polishing machine, Electroplating machine, Assembling machine on the system availability. Here, we may select the maximum value of availability column wise for each subsystem and then finally the maximum of the maximal (availability) would be taken for each subsystem. So, the optimal values of failure and repair rates may be selected accordingly for each subsystem of the Tab manufacturing plant.

Table 1: Decision matrix for the Casting machine Subsystem Availability (Av.)

λ_1 \ μ_1	0.01	0.02	0.03	0.04
0.001	0.6908	0.7155	0.7241	0.7285
0.003	0.6069	0.6677	0.6908	0.7029
0.005	0.5412	0.6259	0.6604	0.6790
0.007	0.4883	0.5890	0.6325	0.6567

Constant values
$\lambda_2 = 0.005, \mu_2 = 0.05;$ $\lambda_3 = 0.003, \mu_3 = 0.03;$ $\lambda_4 = 0.003, \mu_4 = 0.03;$ $\lambda_5 = 0.0025, \mu_5 = 0.02;$ $\lambda_6 = 0.007, \mu_6 = 0.07;$ $\lambda_7 = 0.007, \mu_7 = 0.07;$ $\lambda_8 = 0.004, \mu_8 = 0.04,$

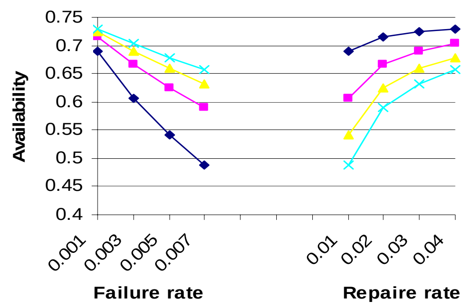

Figure 3: Effect of Failure and Repair Rates

Table 2: Decision Matrix for the Forging machine Subsystem Availability (Av.)

λ_2 \ μ_2	0.05	0.07	0.09	0.11
0.005	0.6908	0.7047	0.7126	0.7155
0.010	0.6461	0.6709	0.6855	0.6908
0.015	0.6069	0.6402	0.6604	0.6677
0.020	0.5722	0.6122	0.6370	0.6461

Constant values
$\lambda_1 = 0.001, \mu_1 = 0.01;$ $\lambda_3 = 0.003, \mu_3 = 0.03;$ $\lambda_4 = 0.003, \mu_4 = 0.03;$ $\lambda_5 = 0.0025, \mu_5 = 0.02;$ $\lambda_6 = 0.007, \mu_6 = 0.07;$ $\lambda_7 = 0.007, \mu_7 = 0.07;$ $\lambda_8 = 0.004, \mu_8 = 0.04,$

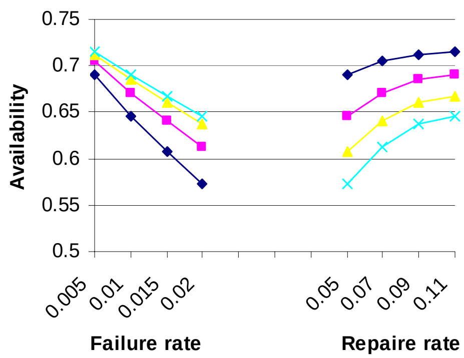

Figure 4: Effect of Failure and Repair Rates

Table 3: Decision Matrix for the Griding machine Sub-system Availability (Av.)

μ_3 / λ_3	0.03	0.09	0.27	0.81
0.003	0.6908	0.6941	0.6959	0.6968
0.005	0.6885	0.6931	0.6956	0.6966
0.007	0.6864	0.6922	0.6952	0.6965
0.009	0.6846	0.6913	0.6948	0.6964

Constant values
$\lambda_1 = 0.001, \mu_1 = 0.01;$
$\lambda_2 = 0.005, \mu_2 = 0.05;$
$\lambda_4 = 0.003, \mu_4 = 0.03;$
$\lambda_5 = 0.0025, \mu_5 = 0.02;$
$\lambda_6 = 0.007, \mu_6 = 0.07;$
$\lambda_7 = 0.007, \mu_7 = 0.07;$
$\lambda_8 = 0.004, \mu_8 = 0.04,$

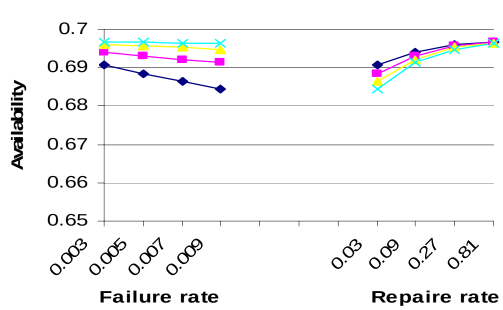

Figure 5: Effect of Failure and Repair Rates

Table 4: Decision Matrix for the Polishing machine Sub-system Availability (Av.)

μ_5 / λ_5	0.02	0.05	0.08	0.11
0.0025	0.6908	0.7285	0.7386	0.7433
0.005	0.6359	0.7029	0.7219	0.7309
0.0075	0.5890	0.6790	0.7060	0.7190
0.010	0.5486	0.6567	0.6908	0.7074

Constant values
$\lambda_1 = 0.001, \mu_1 = 0.01;$
$\lambda_2 = 0.005, \mu_2 = 0.05;$
$\lambda_3 = 0.003, \mu_3 = 0.03;$
$\lambda_4 = 0.003, \mu_4 = 0.03;$
$\lambda_6 = 0.007, \mu_6 = 0.07;$
$\lambda_7 = 0.007, \mu_7 = 0.07;$
$\lambda_8 = 0.004, \mu_8 = 0.04,$

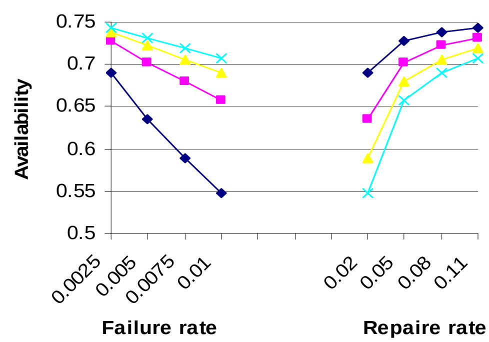

Figure 6: Effect of Failure and Repair Rates

Table 5: Decision Matrix for Electro-plating machine Sub-system Availability (Av.)

μ_6 / λ_6	0.07	0.14	0.21	0.28
0.007	0.6908	0.6923	0.6940	0.6943
0.011	0.6880	0.6915	0.6928	0.6934
0.015	0.6857	0.6899	0.6916	0.6924
0.019	0.6837	0.6887	0.6905	0.6919

Constant values
$\lambda_1 = 0.001, \mu_1 = 0.01;$ $\lambda_2 = 0.005, \mu_2 = 0.05;$ $\lambda_3 = 0.003, \mu_3 = 0.03;$ $\lambda_4 = 0.003, \mu_4 = 0.03;$ $\lambda_5 = 0.0025, \mu_5 = 0.02;$ $\lambda_7 = 0.007, \mu_7 = 0.07;$ $\lambda_8 = 0.004, \mu_8 = 0.04,$

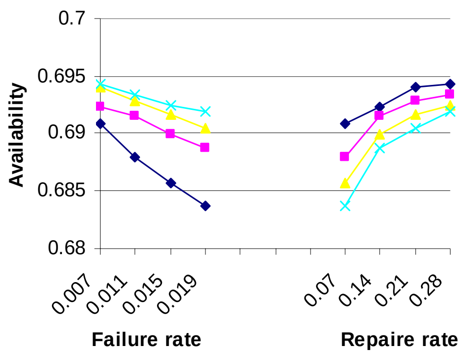

Figure 7: Effect of Failure and Repair Rates

Table 6:Decision Matrix For Assembling machine Sub-system Availability (Av.)

λ_8 \ μ_8	0.04	0.06	0.08	0.10
0.004	0.6908	0.7070	0.7155	0.7206
0.008	0.6461	0.6752	0.6908	0.7004
0.016	0.5722	0.6194	0.6461	0.6633
0.032	0.4656	0.5316	0.5722	0.5996

Constant values
$\lambda_1 = 0.001, \mu_1 = 0.01;$ $\lambda_2 = 0.005, \mu_2 = 0.05;$ $\lambda_3 = 0.003, \mu_3 = 0.03;$ $\lambda_4 = 0.003, \mu_4 = 0.03;$ $\lambda_5 = 0.0025, \mu_5 = 0.02;$ $\lambda_6 = 0.007, \mu_6 = 0.07;$ $\lambda_7 = 0.007, \mu_7 = 0.07;$

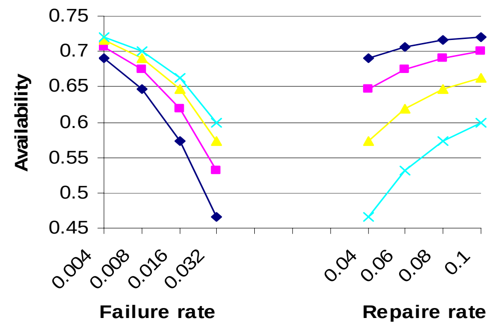

Figure 8: Effect of Failure and Repair Rates

RESULTS AND DISCUSSION

Table 1 shows the effect of failure and repair rates of Casting machine on the availability of the Tab manufacturing plant. It is observed that for some known values of failure and repair rates of Forging machine, Grinding machine, Polishi ng machine, Electroplating machine, Assembling machine,

$(\lambda_2 = 0.005, \mu_2 = 0.05;$
$\lambda_3 = 0.003, \mu_3 = 0.03;$
$\lambda_4 = 0.003,\ \mu_4 = 0.03;$
$\lambda_5 = 0.0025, \mu_5 = 0.02;$
$\lambda_6 = 0.007, \mu_6 = 0.07;$
$\lambda_7 = 0.007, \mu_7 = 0.07;$
$\lambda_8 = 0.004,\ \ \mu_8 = 0.04$) as failure rate (λ_1) of Casting machine increases from 0.001 (once in 1000 hrs) to 0.007(once in 142.85 hrs), the system availability decreases considerably by 20.25%. Similarly, as the repair rate (μ_1) of Casting machine increases from 0.01 (once in 100 hrs) to 0.04(once in 25 hrs), the system availability increases by 3.77%.
From Table 2, it is further observed that as failure rate (λ_2) of Forging machine increases from 0.005 (once in 200 hrs) to 0.020 (once in 50 hrs), the system availability decreases by 11.86%. Similarly, when repair rate (μ_2) of Forging machine decreases from 0.05 (once in 20 hrs) to 0.11(once in 9.09 hrs), then the system availability increases by 2.47%.
Table 3 also reveals the variation of system availability with change in failure rates (λ_3) and repair rates (μ_3) of the Griding machine. As failure rate (λ_3) increases from 0.003 (once in 333.33 hrs) to 0.009 (once in 111.11 hrs), the system availability reduces by .62%. Similarly, when repair rate (μ_3) increases from 0.03(once in 33.33 hrs) to 0.81(once in 1.23 hrs), then the system availability increases by .60%.
Similarly Table 4 shows the variation in availability of Tab manufacturing plant with the change in failure

and repair rates of subsystem Polishing machine (λ_5, μ_5).Further table 4 reveals that failure rate (λ_5) increases from 0.0025 (once in 400 hrs) to 0.010(once in 100 hrs), the system availability reduces by 14.22%. Similarly, when repair rate (μ_5) increases from 0.02(once in 50 hrs) to 0.11(once in 9.09 hrs), then the system availability increases by about 5.25%.

Table 5 also reveals the variation of system availability with change in failure rates (λ_6) and repair rates (μ_6) of the Electroplating machine. As failure rate (λ_6) increases from 0.007 (once in 142.85 hrs) to 0.019(once in 52.63 hrs), the system availability reduces by 0.71%. Similarly, when repair rate (μ_7) increases from 0.07(once in 14.28 hrs) to 0.28(once in 3.57 hrs), then the system availability increases by about .35%.

Table 6 also reveals the variation of system availability with change in failure rates (λ_8) and repair rates (μ_8) of the Assembling machine .As failure rate (λ_8) increases from 0.004 (once in 250 hrs) to 0.032(once in 31.25 hrs), the system availability reduces by 22.52%. Similarly, when repair rate (μ_8) increases from 0.04(once in 25 hrs) to 0.10 (once in 10 hrs), then the system availability increases by about 2.98%.

From Table 1, we may select the maximum value of availability of first column for Casting machine sub system and then for other column also. Finally the maximum of the maximal (availability) would be taken i.e. Av. $_{(max)}$ = 0.7285. Similarly, from table 2 ,3,4,5,and 6 for Forging machine Av. $_{(max)}$ =0.7155, for Grinding machine Av. $_{(max)}$ =0.6968, Polishing machine Av. $_{(max)}$ =0.7433 , Electroplating machine Av. $_{(max)}$ =0.6943 and Assembling machine Av. $_{(max)}$ =0.7206 So, the corresponding optimal values of failure and repair rates may be selected accordingly for each subsystem of the Tab manufacturing plant system and are given in table 7.

Table 7. Optimal Values of Failure and Repair Rates

Sr.No.	λ_i	μ_i	Max.Availability Level
1	0.001	0.04	0.7285
2	0.005	0.11	0.7155
3	0.003	0.81	0.6968
4	0.0025	0.11	0.7433
5	0.007	0.28	0.6943
6	0.004	0.10	0.7206

CONCLUSIONS

The decision support system for Tab manufacturing plant has been developed with the help of mathematical modeling using simple probability considerations. Various decision matrices are developed which facilitate the decision making process regarding maintenance so that the proper maintenance decisions can be made at critical points. Accordingly repair priorities should be given to some particular subsystems of Tab manufacturing plant. Decision matrices as given in tables 1,2 ,3,4,5and 6 clearly reveal that Polishing machine is most critical subsystem as far as maintenance work is concerned. So, it should be given top priority for the repairs as the effect of it's failure/repair rates on system availability is much higher as that of other subsystems. Therefore, repair work should be done in the following order of performance.

Subsystem	Increase in Availability	Rank
D. Polishing machine	5.25%	1st
A. Casting machine	3.77%	2nd
E.Electroplating machine	3.57%	3rd
F.Assembling machine	2.98%	4th
B. Forging machine	2.47%	5th
C. Grinding machine	.60%	6th

Decision matrices (tables 1, 2,3,4,5 and 6) also help in determining the optimal maintenance strategy, which will ensure the maximum availability of the Tab manufacturing plant. The optimum values of failure and repair rates for each subsystem are already given in table 7.

Hence, decision support system is an interactive system to restructure, reformulate, redesign and monitor each of its facilities for the optimal usage of the maintenance resources. This decision model would be very useful in the comparative evaluation of maintenance strategies. So, the findings of this paper will be highly beneficial to the plant management for the corrective and timely execution of proper maintenance decisions and hence to enhance the system's performance

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