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MATHEMATICAL MODELING ANDBEHAVIOUR ANALYSIS OF A REFRIGERATION PLANT

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Abstract: In the current investigation one have picked the Refrigeration Plant arranged in Rohtak District. A refrigeration unit consists of four main components namely Compressor, Condenser, Expansion Deviceand Evaporator. Availability of milk plant is determined with the assistance of RPGT and accessibility of the arrangement of Refrigeration plants are thought to be only viable when all four units are in good operating condition. When each of the four units is in good operating condition, the system operates at maximum efficiency. When three out of four units are in good operating condition, it operates at a decreased capacity. When two or more units fail, the system is in a failed condition. There are separate continuous failure and repair rates for all four units. Graphs are drawn to depict the behavior of the MTSF, Availability of the system and busy period of the server for a particular case.

Keywords: Availability analysis, MTSF, Availability

1. Introduction:

This paper discusses the behavior analysis to analyze transient behavior of repairable Refrigeration plant using RPGT, based on Markov modeling for modeling system parameters equations. The effect of failure and repair of units is examined to realize optimum level of performance of system parameters. Now a day availability / maintainability analysis of process industries is having increased importance which may benefit the industry with higher productivity and lower maintenance activities with costs. Different performance measures used in process industry are indicates to define the performance of a plant in terms of system parameters. Most of these parameters are linked to operational stage while a few of these are useful to design the units at an early stage. A refrigeration unit consists of four main components namely Compressor, Condenser, Expansion Device and Evaporator. This study involves only three subsystems namely Condenser A, Expansion Device B and Evaporator D which have higher failure rates in comparison to Compressor whose failure rate is negligible due to availability of better quality of electricity supply these days, hence not accounted for study, three subsystems under study have parallel subcomponents, hence the system can work in reduced capacity when one unit is working in reduced state. All the three units have different failure distributions; hence on failure of any unit system fails. Fuzzy logic is used to decide the failure of any unit. Graphs and tables are drawn to compare failure and repair rate their effect on the parameters values. The system consists of three non-identical units. Repairs are perfect. The repair order priority is unit A> unit B> unit D. The system is down when any of the units is in failed state, or two units are in reduced state. Failure and repairs are independent.The failure and repair rates of units are takes as constant, transient probability consideration on under Markov-process are helpful to draw the transient state diagram of the system under steady state. Laplace transformations are used to evaluate mean sojourn times of various stage expressions for system parameters are modeled using RPGT. Keeping failure or repair rates of units fixed while varying other for different units, their effect on system performance parameters is given by drawing tables and graphs, followed by discussions. Bhunia et al. (2010) proposed GA for tackling unwavering quality stochastic enhancement issues in a series framework with span part. The review resolved the issue of stochastic unwavering quality streamlining in light of chance imperatives in the series framework. Jieong et al. (2009) utilized a half and half calculation known as GA/PSO for tackling multi-objective streamlining issues. Komal et al. (2009) discussed the reliability, availability, and maintainability analysis gives some plan to carryout structure modification, assuming any required to accomplish superior of the complex mechanical systems. Kumar et al. (2018) talked about the 3:4: G System. Kumari et al. (2021) talked about the benefit examination of an agribusiness harvester plant in consistent state utilizing RPGT. Anchal et al. (2021) examined the SRGM model utilizing differential condition has been proposed, in which two classifications of deficiencies: straightforward and hard as for time in which these happen for disengagement and expulsion after their recognition has been introduced. Kumar et al. (2017) concentrated on the conduct examination in the urea compost industry. Kumar et al. (2019) the primary goal of this paper is to an inspected examination of a washing unit in the paper business using RPGT. Kumar et al. (2018) have concentrated on the conduct examination of a bread framework and eatable petroleum treatment facility plant.

2. Assumptions and Notations

1. Facility of single repair is always available.
2. Repairs and failures are statistically independent.
3. Repair is perfect and repaired system is as good as the new one.

$h_{i:}$ Constantrepair rates

$g_{i:}$ Constantfailure rates

3. Transition Diagrams:

By taking into consideration all the above notations and assumptions, the Transition Diagram of the system is given in Fig. 1.

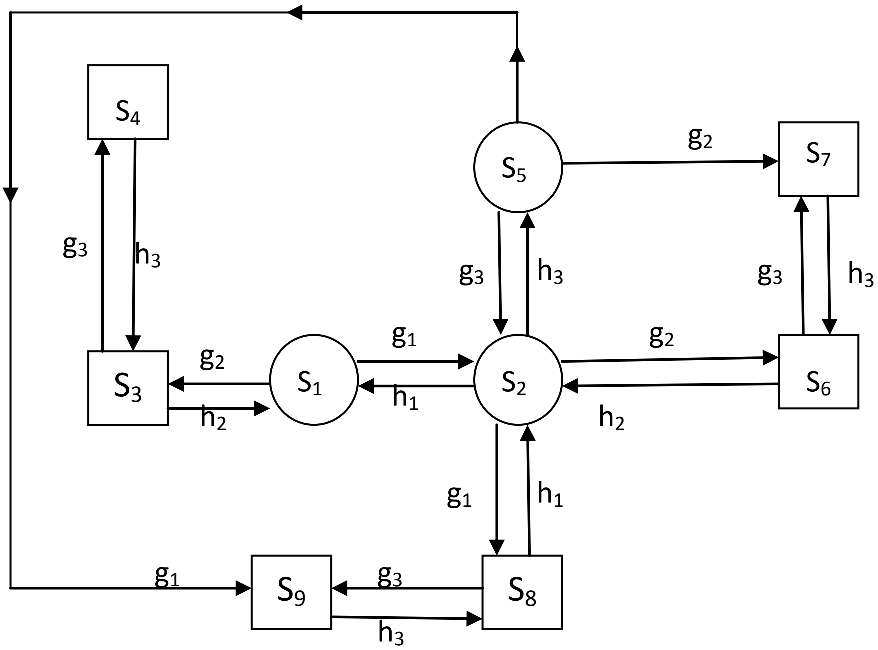

Fig.1: Transition Diagrams

S_1 = A(A)B, S_2 = aAB, S_3 = A(A)b, S_4 = A(A)bM,

S_5 = aABM, S_6 = aAb, S_7 = aAbM, S_8 = aaB,

S_9 = aaBM,

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Table 1:Transition Probabilities

$q_{i,j}(t)$	$p_{i,j} = q^*_{i,j}(t)$
$q_{1,2}(t) = g_1\, e^{-(g_1+g_2)t}$	$p_{1,2} = g_1/(g_1+g_2)$
$q_{1,3}(t) = g_2\, e^{-(g_1+g_2)t}$	$p_{1,3} = g_1/(g_1+g_2)$
$q_{2,1}(t) = h_1\, e^{-(g_1+g_2+g_3+h_1)t}$	$p_{2,1} = g_1/(g_1+g_2+g_3+h_1)$
$q_{2,5}(t) = g_3\, e^{-(g_1+g_2+g_3+h_1)t}$	$p_{2,5} = g_3/(g_1+g_2+g_3+h_1)$
$q_{2,6}(t) = g_2\, e^{-(g_1+g_2+g_3+h_1)t}$	$p_{2,6} = g_2/(g_1+g_2+g_3+h_1)$
$q_{2,8}(t) = g_1\, e^{-(g_1+g_2+g_3+h_1)t}$	$p_{2,8} = g_1/(g_1+g_2+g_3+h_1)$
$q_{3,1}(t) = h_2\, e^{-(h_2+g_3)t}$	$p_{3,1} = h_2/(h_2+g_3)$
$q_{3,4}(t) = g_3\, e^{-(h_2+g_3)t}$	$p_{3,4} = g_3/(h_2+g_3)$
$q_{4,3}(t) = h_3\, e^{-h_3 t}$	$p_{4,3} = 1$
$q_{5,2}(t) = h_3\, e^{-(g_1+g_2+h_3)t}$	$p_{5,2} = h_3/(g_1+g_2+h_3)$
$q_{5,7}(t) = g_2\, e^{-(g_1+g_2+h_3)t}$	$p_{5,7} = g_2/(g_1+g_2+h_3)$
$q_{5,9}(t) = g_1\, e^{-(g_1+g_2+h_3)t}$	$p_{5,9} = g_1/(g_1+g_2+h_3)$
$q_{6,2}(t) = h_2\, e^{-(g_3+h_2)t}$	$p_{6,2} = h_2/(g_3+h_2)$
$q_{6,7}(t) = g_3\, e^{-(g_3+h_2)t}$	$p_{6,7} = g_3/(g_3+h_2)$
$q_{7,6}(t) = h_3\, e^{-h_3 t}$	$p_{7,6} = 1$
$q_{8,2}(t) = h_1\, e^{-(g_3+h_1)t}$	$p_{8,2} = h_1/(h_1+g_3)$
$q_{8,9}(t) = g_3\, e^{-(g_3+h_1)t}$	$p_{8,9} = g_3/(h_1+g_3)$
$q_{9,8}(t) = h_3 e^{-h_3 t}$	$p_{9,8} = 1$
	$p_{1,3} + p_{1,3} = 1$

$p_{2,1} + p_{2,5} + p_{2,6} + p_{,8} = 1$; $p_{3,1} + p_{3,4} = 1$; $p_{5,2} + p_{5,7} + p_{5,9} = 1$; $p_{6,2} + p_{6,7} = 1$

$p_{8,2} + p_{8,9} = 1$

Table 2: Mean Sojourn Times

$R_i(t)$	$\mu_i = R_i^*(0)$
$R_1(t) = e^{-(g_1+g_2)t}$	$\mu_1 = 1/(g_1+g_2)$
$R_2(t) = e^{-(g_1+g_2+g_3+h_1)t}$	$\mu_2 = 1/(g_1+g_2+g_3+h_1)$
$R_3(t) = e^{-(h_2+g_3)t}$	$\mu_3 = 1/(h_2+g_3)$
$R_4(t) = e^{-h_3 t}$	$\mu_4 = 1/h_3$
$R_5(t) = e^{-(g_1+g_2+h_3)t}$	$\mu_5 = 1/(g_1+g_2+h_3)$
$R_6(t) = e^{-(g_3+h_2)t}$	$\mu_6 = 1/(g_3+h_2)$
$R_7(t) = e^{-h_3 t}$	$\mu_7 = 1/h_3$
$R_8(t) = e^{-(h_1+g_3)t}$	$\mu_8 = 1/(h_1+g_3)$
	$\mu_9 = 1/h_3$

R_9 (t) = $e^{-h_3 t}$	

4. Evaluation of Path Probabilities:

Applying RPGT and utilizing '1' as initial-state of the framework, we discovery transition probability aspects of all accessible states from first state 'ξ' = '1' . We will discover probabilities after state '1' to various vertices which are defined as follows:

$V_{1,1}$ = 1 (Verified)

$V_{1,2}$ = (1, 2)/ {1 - (2, 5, 2)} [1 - (2, 6, 2)/{1 - (6, 7, 6)}][1 - (2, 8, 2)/{1 - (8, 9, 8)}]

= $p_{1,2}/(1 - p_{2,5}\, p_{5,2})[1 - \{(p_{2,6}\, p_{6,2}/(1 - p_{6,7}\, p_{7,6})\}]\, [1 - \{(p_{2,8}\, p_{8,2}/(1 - p_{8,9}\, p_{9,8})\}]$

$V_{1,3}$ = ……Continuous

Transition state probabilities from base state '2' are

$V_{2,1}$ = (2, 1)/[{1 - (1, 3, 1)}/{1 - (3, 4, 3)}]

= $p_{2,1}/\{(1 - p_{1,3}\, p_{3,1})/(1 - p_{3,4}\, p_{4,3})\}$

$V_{2,2}$ = 1

$V_{2,3}$ = (2, 1, 3)/[{1 - (1, 3, 1)}/{1 - (3, 4, 3)}]{1 - (3, 4, 3)}

= $p_{2,1}\, p_{1,3}/[\{(1 - p_{1,3}\, p_{3,1})/(1 - p_{3,4}\, p_{4,3})\}(1 - p_{3,4}\, p_{4,3})]$

$V_{2,4}$ =…….Continuous

5. Methodology

Mean time to system failure (T_0): Regenerative un-failed states to which the framework can transit (initial state '2'), earlier incoming any fizzled state are: 'i' = 1, 2, 5 attractive 'ξ' = '1'

$T_0 = (V_{1,1}\, \mu_1 + V_{1,2}\, \mu_2 + V_{1,5}\, \mu_5)/\ \{1 - (1, 2, 1)\}$

Availability of the system (A_0): Regenerative states at which the framework is accessible are 'i' = 1, 2, 5 attractive 'ξ' = '1' whole fraction of time for which the framework is accessible is assumed by

$A_0 = \left[\sum_j V_{\xi,j}\, , f_j\, ,\ \mu_j\right] \div \left[\sum_i V_{\xi,i}\, , f_j\, ,\ \mu_i^1\right]$

$A_0 = (V_{2,1}\, \mu_1 + V_{2,2}\, \mu_2 + V_{2,5}\, \mu_5)/Z_1$

$\therefore Z = V_{1,1}\, \mu_1 + V_{1,2}\, \mu_2 + V_{1,3}\, \mu_3 + V_{1,4}\, \mu_4 + V_{1,5}\, \mu_5 + V_{1,6}\, \mu_6 + V_{1,7}\, \mu_7 + V_{1,8}\, \mu_8 + V_{1,9}\, \mu_9$

$\therefore Z_1 = V_{2,1}\mu_1 + V_{2,2}\mu_2 + V_{2,3}\mu_3 + V_{2,4}\mu_4 + V_{2,5}\mu_5 + V_{2,6}\mu_6 + V_{2,7}\mu_7 + V_{2,8}\mu_8 + V_{2,9}\mu_9$

Server of busy period (B_0): Regenerative states where server is busy are $2 \le j \le 9$, attractive ξ = '1', whole fraction of time for which server remains eventful is by equation

$B_0 = \left[\sum_j V_{\xi,j}, n_j\right] \div \left[\sum_i V_{\xi,i}, \mu_i^1\right]$

$B_0 = (V_{1,2}\mu_2 + V_{1,3}\mu_3 + V_{1,4}\mu_4 + V_{1,5}\mu_5 + V_{1,6}\mu_6 + V_{1,7}\mu_7 + V_{1,8}\mu_8 + V_{1,9}\mu_9)/D$

$= 1 - (\mu_1/D)$

Expected number of server visit's (V_0): Regenerative states where repair man does this job j = 2, 5 taking 'ξ' = '1', number of visit by repair man is given by

$V_0 = \left[\sum_j V_{\xi,j}\right] \div \left[\sum_i V_{\xi,i}, \mu_i^1\right]$

$V_0 = (V_{1,2} + V_{1,5})/D$

6. Analytical Case:

RPGT andData Analysis Results

Fix;$g_i = g$, $h_i = h$

Mean Time to System Failure (MTSF) (T_0)

Table 3: Mean Time to System Failure (T_0)

	h = 0.50	h = 0.60	h = 0.70
g = 0.10	9.20	9.35	9.48
g = 0.20	7.85	7.90	8.03
g = 0.30	5.04	5.23	5.35

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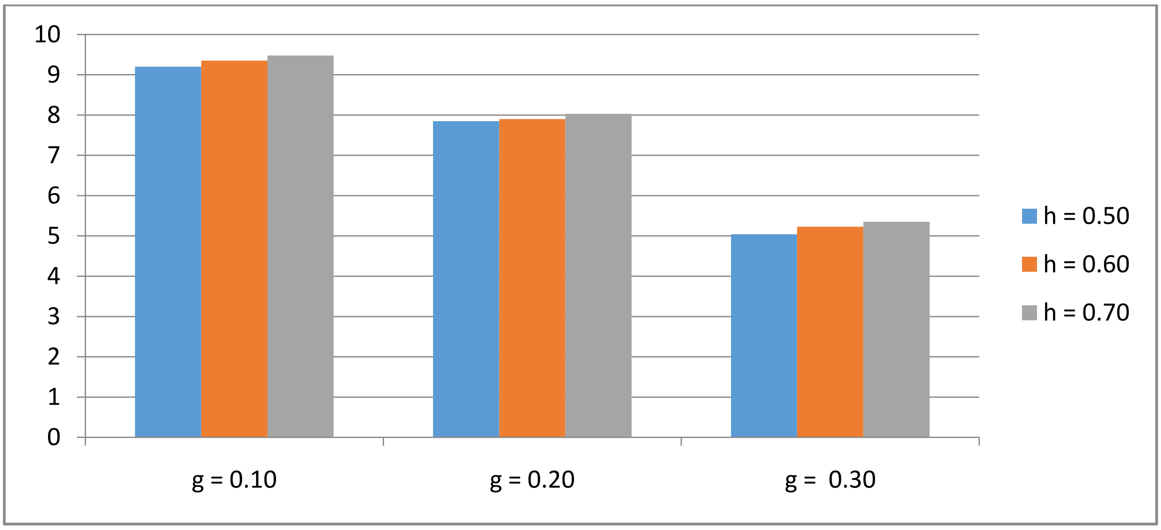

Fig. 2: Mean Time to System Failure

The MTSF falls with an increase in subunit failure rates, according to fig. 2 and table 3. However, the failure rates should be at the absolute lowest level while MTSF repair rates should be as high as possible.

Availability of the System (A_0):

Table 4: Availability of the System (A_0)

	h = 0.50	h = 0.60	h = 0.70
g = 0.10	0.782	0.887	0.920
g = 0.20	0.522	0.685	0.838
g = 0.30	0.369	0.448	0.536

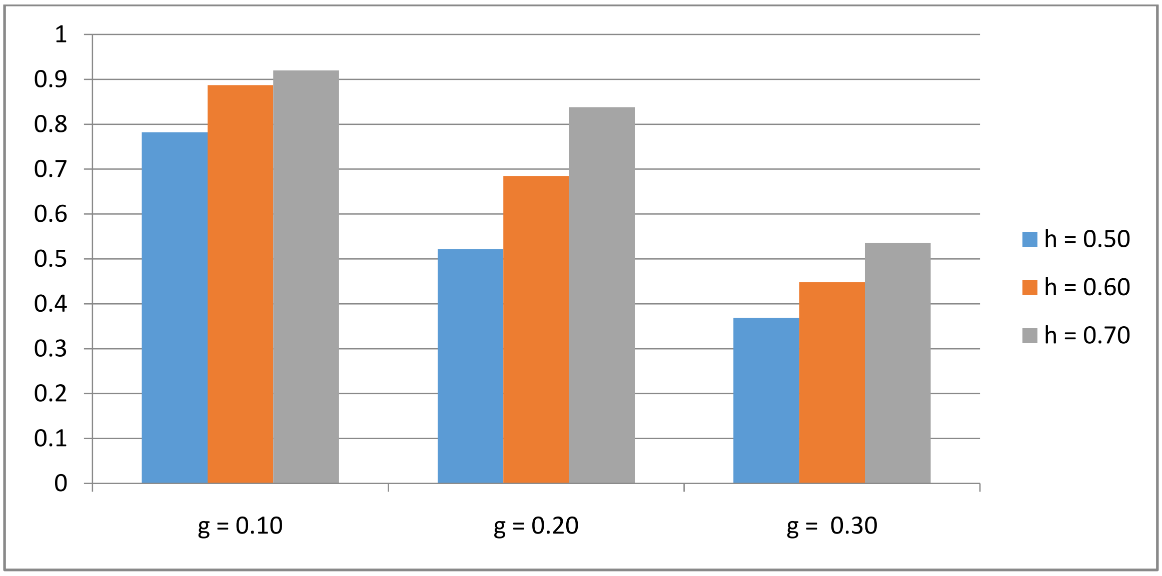

Fig.3: Availability of the System

According to fig. 3 and Table 4, availability rises with higher repair rates, and declines with higher failure rates, which is consistent with current market trends.

Server of the Busy Period (B_0):

Table 5: Server of the Busy Period (B_0)

	h = 0.50	h = 0.60	h = 0.70
g = 0.10	0.664	0.623	0.582
g = 0.20	0.720	0.675	0.645
g = 0.30	0.819	0.709	0.680

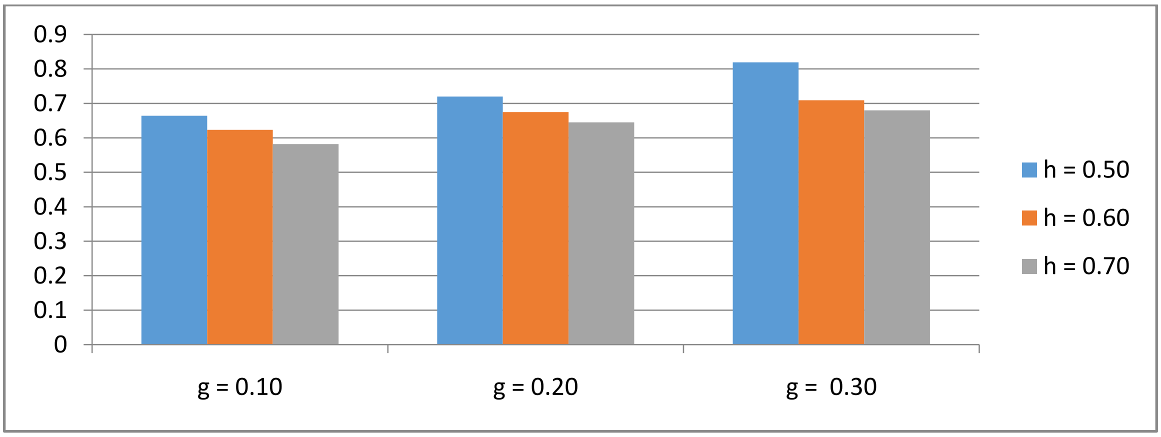

Fig.4: Server of the Busy Period

According to Table 5 and Fig. 4, the busy period value drops when repair rates rise, and it rises as failure rates rise, which is consistent with the trends observed in real-world situations. However, the ideal value of the repair rates peak time should be as low as is practical.

Expected Number of server's visits (V_0):

Table 6: Expected Number of server's visits (V_0)

	h = 0.50	h = 0.60	h = 0.70
g = 0.10	0.121	0.114	0.107
g = 0.20	0.140	0.126	0.115
g = 0.30	0.143	0.139	0.125

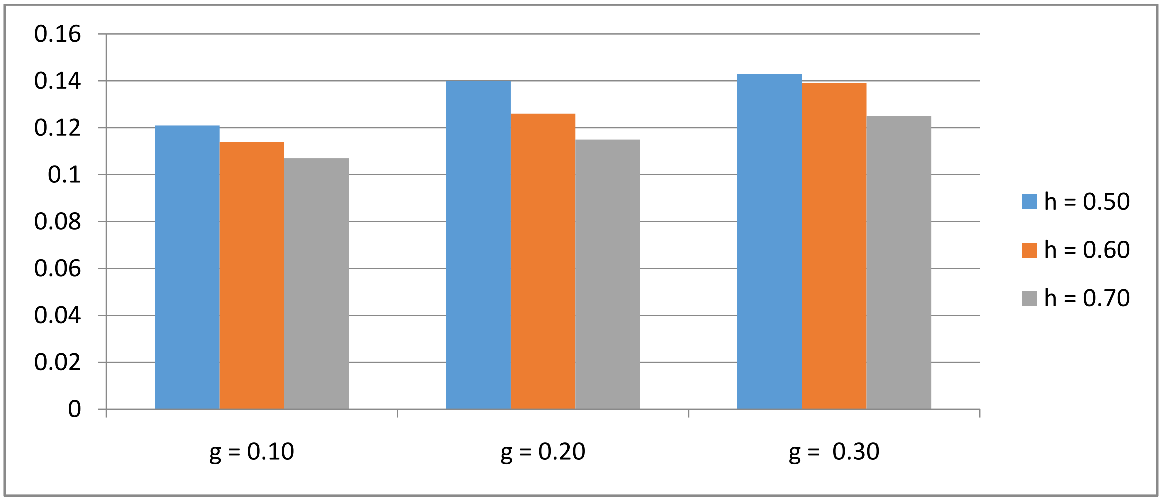

Fig. 5: Expected Number of Server's Visits

The estimated fractional number of inspections performed by repair personnel is found to be directly correlated with subsystem failure and repair rates.

7. Conclusion:

The refrigeration plant can be run on a yearly basis as throughout the year. There is availability of many types or the other types of milk/fruits. Each plant can prepare the readymade packed milk/fruits of priority items. Refrigeration is made for fresh/ stored milk/fruits, for which these are many crushing/ pressing units available in a plant. If one or more crushing/ pressing units fail, then the whole of the system works in reduced capacity of the number of crushing / pressing units exceed a particular number, then the crushing unit fails causing the whole system failure. As the shelf life of fresh milk/fruit is very small, so to increase its storage life same preservative and other ingredients are added as per the requirements of a particular flavor, this process of addition of ingredients and preservatives is called processing, in large refrigeration plant there is number of processing units working in parallel. Failure of one or more but less than a particular level reduces the efficiency of the processing unit, hence that of the whole plant. To have optimum value of system parameters management may control the failure and repair rates of units depending upon the availability of finances and market circumstances.

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