Mathematical Modeling and Optimization of System Parameters of Feed Plant Using Machine Learning

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Keywords: Machine Learning Algorithms, Regenerative Point Graphical Technique (RPGT).

Abstract: In this study, RPGT is applied for mathematical modelling system constraints of cattle, poultry, and fish feed plant and stand optimized by machine learning. The plant is made up of three grinder units (A1A2A3) that grind three distinct raw materials into precipitate depending on the type of feed that needs to be prepared, as well as a single cold standby (A) aimed at aimed at all these grinders, each of these grinders has a common standby grinder that is operated by an imperfect switch-over device whose probability of successful replacing is p, so that, if any one of the three grinders fails, the standby grinder can still input the ingredients into the system, a mixer (B) that combines the powder by syrup, using stuffing unit and a packing (D). Optimization of system parameters is carried out using Machine Learning Algorithms as Linear SVC Classifier (LC), Logistic Regression (LR), and Decision Tree Classifier (DT). Tables and charts are likewise created to explain the system's practical trend using specific situations.

1 INTRODUCTION

Due to religious restrictions, the beef and pork feed industries in India are nonexistent, and these only produce dairy, poultry, and aqua feeds. Numerous feed plants have sprouted up in the NCR region (especially Rohtak-Haryana) because of the high standard and international standard of the feeds produced there, as well as the abundance of materials readily available for their production. Maize, rice bran, groundnuts, and other raw materials are utilized in a chicken, cow, and fish feed facility. Due to the fertile soil and numerous rivers that bring water to the region, the agriculture industry in the Rohtak region is thriving. Farmers grow a wide variety of crops, including Makka, barely, maize, wheat, and rice. They are also engaged in fish farming and work in other sectors. Numerous cattle feed plants, or cattle feed plants, have sprung up in the region to supplement the cattle feed. In addition, since fish require water to grow and the Yamuna, and Ghaggar rivers provide abundant water; many farmers in the region have chosen to pursue fish farming as a profession.

System Description. In a feed plant, there are typically three grinders that grind the different ingredients. Each of these grinders has a common standby grinder that is operated by an imperfect switch-over device whose probability of successful replacing is p, so that, if any one of the three grinders fails, the standby grinders can still input the ingredients into the system. Following processing in mixtures, the feed is transported via conveyor belts to open fields where it is derivate, cold weighed, and packaged. These ground in grinded are mixed with a bonding material. Thus, in a feed plant, there are three different types of unit grinder's mixture and packing units arranged in series. If any one of these flops, the organization is in a down state, or fails. However, the standby unit has a lower working capacity than the main grinders, so when it is online, the plant's working capacity is decreased.

The plant has three grinders, A_1, A_2, A_3 which mills the uncooked resources there is a cold stand-in grinder; it is swapped in through an imperfect switch-over device to altogether these three grinders, a blender unit B which mixes the raw resources in the obligatory 0fraction by treacle and a considering of

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stuffing unit. When the backup unit is online, the classification operates at a reduced rate. The arrangement malfunctions when a standby unit, mixer, or packing repair unit fails. Performance analysis also identifies the primary contributors to repairable spinning machines. It has been created to increase system availability by managing maintenance factors and minimum maintenance and repair rates, which are crucial to system availability. Priority in repair to the three units is in order A>B>D taking single repair facility is who is always available carries out all types of repairs. System parameters are obtained using RPGT. (Shakuntla et al., 2011) discussed the behavior analysis of polytube using supplementary technique; the behavior of a bread plant was examined by (Kumar et al. 2018). To do a sensitivity analysis on a cold standby framework made up of two identical units with server failure and prioritized for preventative maintenance, (Kumar et al. 2019) used RPGT. The comparative analysis of the subsystem failed simultaneously was discussed by (Shakuntla et al. 2011). In a paper mill washing unit, (Kumar et al. 2019) investigated mathematical formulation and behavior study. PSO was used by (Kumari et al. 2021) to research limited situations. Using a heuristic approach, (Rajbala et al. 2022) investigated the redundancy allocation problem in the cylinder manufacturing plant. The tables and graphs are created using analytical cases, and they are then discussed and concluded.

2 ASSUMPTION AND NOTATIONS

1. There is single repairman who is always presented.

2. The circulations of failure/repair periods are constant and diverse.

3. Nothing can flop when organization is in unsuccessful state.

4. The organization is conferred on behalf of steady-state circumstances.

$R_i(t)$: Reliability of the organization at period t, specified that classification go in the un-failed Re-forming state 'i' at t = 0.

μ_i : Mean sojourn time expended in state i, previously visiting several additional states.

$\mu_i = \int_0^\infty R_i(t)dt$

ξ : Base state of the organization.

f_j : Fuzziness portion of the j-state.

A/a : Unit in working state / failed state, correspondingly for other units.

w_i/λ_i : Denote repair failure rates of units

p: probability of switching successfully

3 TRANSITION DIAGRAM

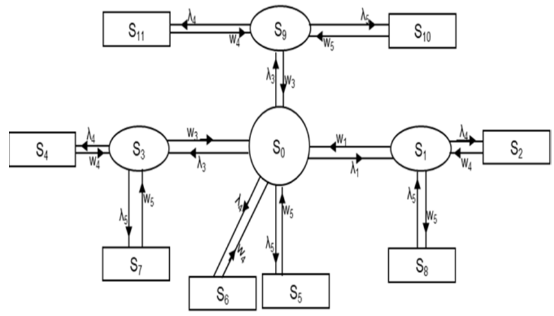

Figure 1: Transition Diagram of the feed plant.

Where various states are as under,

$S_0 = A_1A_2A_3BD(a)$; $S_1 = AA_2A_3BD(a_0)$; $S_2 = AA_2A_3bD$; $S_3 = A_1AA_3BD(a_2)$; $S_4 = A_1AA_3bD(a_2)$; $S_5 = A_1A_2A_3Bd$; $S_6 = A_1A_2A_3bD$; $S_7 = A_1AA_3Bd(a_2)$; $S_8 = AA_2A_3Bd(a_1)$; $S_9 = A_1A_2ABD(a_3)$; $S_{10} = A_1A_2ABd(a_3)$; $S_{11} = A_1A_2AbD(a_3)$

3.1 Probability Density Function ($Q_{i,j}^{(t)}$)

$q_{0,1}= \lambda_1 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$

$q_{0,5}= \lambda_5 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$

$q_{0,6}= \lambda_6 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$

$q_{0,3}= \lambda_2 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$

$q_{0,9}= \lambda_3 e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$

$q_{1,2}= \lambda_4 e^{-(\lambda_4+\lambda_5+w_1)t}$; $q_{1,8}= \lambda_5 e^{-(\lambda_4+\lambda_5+w_1)t}$

$q_{1,0}= w_1 e^{-(\lambda_4+\lambda_5+w_1)t}$; $q_{3,0}= w_2 e^{-(w_2+\lambda_5+\lambda_4)t}$

$q_{3,7}= \lambda_5 e^{-(w_2+\lambda_5+\lambda_4)t}$; $q_{3,4}= \lambda_4 e^{-(w_2+\lambda_5+\lambda_4)t}$

$q_{2,1} = q_{11,9} = q_{6,0}= q_{4,3}= w_4 e^{-w_4 t}$

$q_{10,9}= q_{8,1} = q_{7,3} = q_{5,0}= w_5 e^{-w_5 t}$

$q_{9,0}= w_3 e^{-(w_3+\lambda_5+\lambda_4)t}$; $q_{9,10}= \lambda_5 e^{-(w_3+\lambda_5+\lambda_4)t}$

$q_{9,11}= \lambda_4 e^{-(w_3+\lambda_5+\lambda_4)t}$

Cumulative Density Functions in moving from state 'i' to state 'j' by taking Laplace Transform of above functions, $P_{ij} = q^*_{i,j}{}^{(t)}$, for infinite time intervals is given as under: -

$p_{0,1}= \lambda_1/(\lambda_1+\lambda_3+\lambda_4+\lambda_2+\lambda_5)$,; $p_{0,5}= \lambda_5/(\lambda_1+\lambda_4+\lambda_3+\lambda_2+\lambda_5)$,; $p_{0,6}= \lambda_6/(\lambda_1+\lambda_3+\lambda_4+\lambda_2+\lambda_5)$; $p_{0,3}= \lambda_2/(\lambda_1+\lambda_3+\lambda_4+\lambda_2+\lambda_5)$; $p_{0,9}= \lambda_3/(\lambda_1+\lambda_4+\lambda_3+\lambda_2+\lambda_5)$; $p_{1,2}= \lambda_4/(\lambda_5+\lambda_2+w_1)$; $p_{1,8}= \lambda_5/(\lambda_5+\lambda_2+w_1)$; $p_{1,0}= w_1/(\lambda_5+\lambda_2+w_1)$; $p_{3,0}= w_2/(w_2+\lambda_4+\lambda_5)$; $p_{3,7}= \lambda_5/(w_2+\lambda_4+\lambda_5)$; $p_{3,4}=$

$\lambda_4/(w_2+\lambda_5+\lambda_4)$; $p_{9,0}= w_3/(w_3+\lambda_4+\lambda_5)$; $p_{9,10}= \lambda_5/(w_3+\lambda_5+\lambda_4)$, $p_{9,11}= \lambda_4/(w_3+\lambda_5+\lambda_4)$

3.2 Probability Density Functions Ri(t) and Mean Sojourn Times μi=Ri*(0)

$R_0^{(t)}= e^{-(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)t}$; $R_1^{(t)}= e^{-(\lambda_4+\lambda_5+W_1)t}$; $R_2^{(t)}= e^{-(w_4)t}$; $R_3^{(t)}= e^{-(w_2+\lambda_5+\lambda_4)t}$; $R_{11}^{(t)} = R_6^{(t)} = R_4^{(t)}= e^{-w_4 t}$; $R_{10}^{(t)} = R_8^{(t)} = R_7^{(t)} = R_5^{(t)}= e^{-w_5 t}$; $R_9^{(t)}= e^{-(w_3+\lambda_5+\lambda_4)t}$

Value of the parameter μ_i giving Mean Sojourn Times

$\mu_0 = 1/(\lambda_1+\lambda_5+\lambda_4+\lambda_2+\lambda_3)$; $\mu_1 = 1/(\lambda_4+\lambda_5+w_1)$; $\mu_3 = 1/(w_2+\lambda_5+\lambda_4)$; $\mu_2 =\mu_4 =\mu_{11} =\mu_6 = 1/(w_4)$; $\mu_7 =\mu_5 =\mu_{10} =\mu_8 = 1/w_5$; $\mu_9 = 1/(w_3+\lambda_5+\lambda_4)$

3.2.1 Transition Probabilities from the Initial Vertex '0' (or Base State)

$V_{0,0} = 1$ (Verified); $V_{0,1} = p_{0,1}/(1-p_{1,2}p_{2,1})\,(1-p_{1,8}p_{8,1})$
$V_{0,2} = [\{\lambda_1/(\lambda_1+\lambda_5+\lambda_2+\lambda_4+\lambda_3)\}\{\lambda_4/(\lambda_5+\lambda_4+w_1)\}]/[\{1-(\lambda_5/\lambda_4+\lambda_5+w_1)\}]$; $V_{0,3}$ = ……….Continuous

MTSF (T_0): The working states to which system can join from primary state '0', earlier going one down state are: 'i' = 2, 4, 5, 6, 7, 8, 10, 11. Taking initial state or base state as 'ξ' = '0'.

$$T_0= \left[\Sigma_{i,sr}\left\{\frac{\left\{pr\left(\xi\xrightarrow{sr(sff)}i\right)\right\}\mu i}{\Pi_{m_1\neq\xi}\{1-V_{\overline{m_1m_1}}\}}\right\}\right] \div \left[1-\Sigma_{sr}\left\{\frac{\left\{pr\left(\xi\xrightarrow{sr(sff)}\xi\right)\right\}}{\Pi_{m_2\neq\xi}\{1-V_{\overline{m_2m_2}}\}}\right\}\right] \quad (1)$$

$= (\mu_0+\{p_{0,1}/(1-p_{1,2}p_{2,1})\;(1-p_{1,8}p_{8,1})\;\mu_1\} +\{[\{\lambda_2/(\lambda_1+\lambda_3+\lambda_5+\lambda_4+\lambda_2)\}]/[\{1-\lambda_5(w_2+\lambda_5+\lambda_4)\}\{1-\lambda_4(w_2+\lambda_5+\lambda_4)\}]\;\mu_3\} +\{[\{\lambda_3/(\lambda_1+\lambda_4+\lambda_3+\lambda_2+\lambda_5)\}]/[\{1-\lambda_5(w_3+\lambda_5+\lambda_4)\}\;[\{1-\lambda_4(w_3+\lambda_4+\lambda_5)\}]\;\mu_9)\}$

Availability of the System: The states (regenerative) classification is in partial / full working state are 'j' = 0, 1, 3, 9 and all states are regenerative, taking 'ξ' = '0' the total fractional availability using RPGT is given by

$$A_0= \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\to}j)\}fj,\mu j}{\Pi_{m_1\neq\xi}\{1-V_{\overline{m_1m_1}}\}}\right\}\right]\div\left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\to}i)\}\mu_i^1}{\Pi_{m_2\neq\xi}\{1-V_{\overline{m_2m_2}}\}}\right\}\right] \quad (2)$$

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

Busy Period of the Server: The states in which server is busy for inspection/ repairing the units are 'j' = 1 to 11, taking ξ = '0', the using RPGT is given by

$$B_0= \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\to}j)\},nj}{\Pi_{m_1\neq\xi}\{1-V_{\overline{m_1m_1}}\}}\right\}\right]\div\left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\to}i)\}\mu_i^1}{\Pi_{m_2\neq\xi}\{1-V_{\overline{m_2m_2}}\}}\right\}\right] \quad (3)$$

$$= \left[\Sigma_j V_{\xi,j}, n_j\right] \div \left[\Sigma_i V_{\xi,i}, \mu_i^1\right]$$

Expected Number of Examinations by the repair man (V_0): The situations where the overhaul man visits anew are j = 1, 3, 9 the reformative states stand i = 0 - 11, and 'ξ' = '0',

$$V_0 = \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\to}j)\}}{\Pi_{k_1\neq\xi}\{1-V_{\overline{k_1k_1}}\}}\right\}\right]\div\left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\to}i)\}\mu_i^1}{\Pi_{k_2\neq\xi}\{1-V_{\overline{k_2k_2}}\}}\right\}\right] \quad (4)$$

$$= \left[\Sigma_j V_{\xi,j}\right] \div \left[\Sigma_i V_{\xi,i}, \mu_i^1\right]$$

4 MODEL EVALUATION

To evaluate the implementation of our model performance, we have estimated different execution evaluation confusion matrix (Recall, Accuracy Precision, and F1- Measure). The evaluation of model phase proposes to appraise the generalization precision exactness of the design model on an

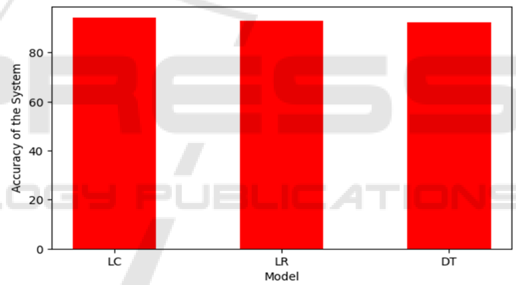

Figure 2: Comparison between Accuracy of models.

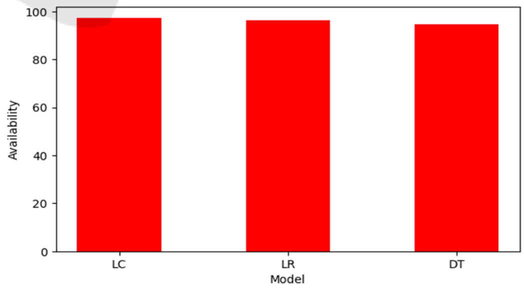

Figure 3: Comparison between Availability of models.

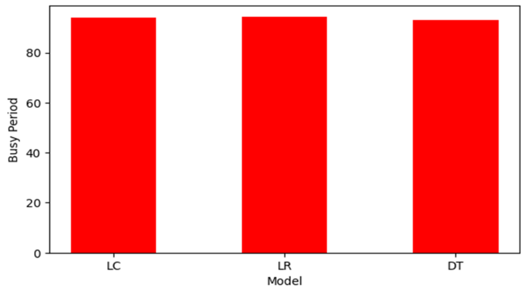

Figure 4: Comparison between Busy periods of models.

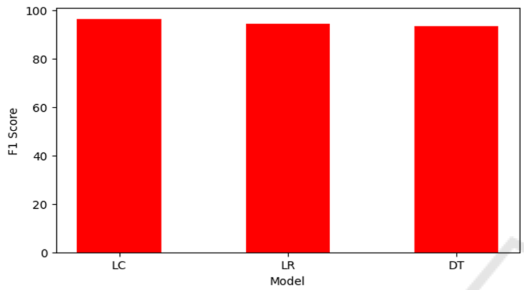

Figure 5: Comparison between F1 score of models.

Availability of the System by applying the precision, MTSF, **Busy Period**, Expected Number of repair man, that are imported from the metrics module available into the Scikit-learn Python library that depends on the following formula in equations 1, 2, 3 and 4 respectively. Overall, the availability analysis is an important tool for identifying the factors that impact the production and profitability of a feed plant [1, 2, 3]. By understanding these factors, plant managers can make informed decisions about investments in equipment, raw materials, and labor that can improve production efficiency and profitability [4, 5, 6,].

Dataset: Availability analysis of a fish feed plant can benefit from the use of machine learning for dataset analysis. Machine learning algorithms can assistance to identify decorations and trends in large datasets that may not be closely apparent to human analysts. This can help to improve the accuracy of the availability analysis and enable plant managers to make more informed decisions about how to improve production efficiency and profitability. For example, machine learning algorithms can be trained on historical data from the plant to predict future demand for feed products. This can help managers to adjust production levels and raw material orders to match expected demand, reducing waste and improving profitability. Similarly, machine learning can be used to identify patterns in raw material availability and price fluctuations, enabling managers to optimize purchasing decisions and reduce costs [4, 5, 6,]. Another potential application of machine learning in availability analysis is predictive maintenance. By scrutinizing statistics from machine beams and added fonts, machine learning algorithms dismiss identifies patterns that could indicate an impending breakdown or maintenance issue.

Table 1: Table of parameter.

W (w1, w2, -------, wn)	$\lambda(\lambda 1, \lambda 2, \ldots \ldots \lambda n)$	**S (s1, s2, -----, sn)**	**p**
(0-50, 51-100)	**0 to 0.1**	**(0-50, 51-100)**	**(0-75)**

This can enable plant managers to schedule maintenance proactively, reducing downtime and improving overall equipment availability. Overall, machine learning can remain a commanding tool for educating the accuracy and efficiency of availability analysis for poultry, cattle, and fish feed plant. By enabling more accurate predictions and insights, machine learning can help plant managers to optimize production, reduce costs, and improve profitability in Table 1.

5 RESULTS AND DISCUSSION

In general, availability analysis involves examining the factors that influence the availability of a particular product or service. For a poultry, cattle, or fish feed plant, these factors might include the availability of raw materials, labor, equipment, and other resources required for production. The analysis would also consider any constraints that might limit the plant's ability to produce feed, such as market demand or regulatory requirements. According to Table 2, fig. 2, Fig. 3, Fig. 4 and Fig. 5 show, comparison among model of linear classifier is better than other model of machine learning.

Table 2: Performance of model.

Model	MTSF	Expected Number of visits by repair man	Busy Period	Availability
Linear SVC Classifier	0.941	0.961	0.941	0.97
Logistic Regression	0.9312	0.9412	0.942	.96
Decision Tree Classifier	0.9234	0.9323	0.932	.94

Without more specific information about the plant and the analysis conducted, it is difficult to provide a meaningful discussion of the results. However, some potential areas for discussion might include:

- The availability of key raw materials: If the availability analysis identified a shortage or high cost of key raw materials, such as soybean meal or corn, this could have significant implications for the plant's ability to produce feed at a reasonable cost.
- Labor availability and skill levels: If the plant relies on skilled labor to operate machinery and produce feed, a shortage of qualified workers could limit production capacity.
- Equipment availability and maintenance: If the plant relies on specialized equipment, such as pellet mills or extruders, any breakdowns or maintenance issues could reduce production capacity and profitability.
- Market demand and competition: The availability analysis might also consider the demand for feed products in the local market and the level of competition from other feed producers. If the market is saturated or demand is low, this could limit the plant's ability to sell its products at a profitable price.

Overall, the availability analysis is an important tool for identifying the factors that impact the production and profitability of a feed plant. By understanding these factors, plant managers can make informed decisions about investments in equipment, raw materials, and labor that can improve production efficiency and profitability.

6 CONCLUSION

The results of the behavior analysis can be used to optimize the input variables for the poultry, cattle, or fish feed plant. For poultry, cattle, or fish feed plant, these factors might include the availability of raw materials, labor, equipment, and other resources required for production. By identifying which input variables have the greatest impact on the output variable, decision-makers can make informed choices about which variables to prioritize for optimization. This can help to improve the efficiency and profitability of the industry, as well as the quality of the final product. These insights can be used to optimize processing parameters, improve the quality of raw materials, and ultimately increase the efficiency and profitability of the industry.

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