Reliability Analysis for the Food Manufacturing Industry

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The present study aims to analyze the main reliability measures for packing equipment used in the production process of corn chips. The Anderson-Darling test was used to evaluate the best distribution of the data collected, showing the lognormal distribution as the best model for the data. We used the Minitab v.17 software for the probability functions of some statistical models. The results showed an MTTF indicator at 2.5 days and R(t)=0.47. Furthermore, the packaging equipment depends on maintenance actions having only a 47% chance of not failing when in operation.
Keywords: Reliability. Lognormal. MTTF. Hypothesis Test.

The globalized economy and the relentless chase of recovery from the economic crisis have demanded companies to have a higher degree of control. So, the organizations have sought new management tools that point to greater competitiveness through the quality and productivity of products, processes, and services [1].

The goal of better management is always to seek higher profitability, cost-reduction, increase productivity, promoting the company's growth and competitiveness in a short-time. So, growing productivity implies a better use of employees, machines, energy, and fuel consumed raw materials, and other issues [2].

The data presented implies the vulnerability of the productivity indicator. The impact caused by equipment failures was discussed in this paper, evaluating the Reliability Centered Maintenance (RCM) management scenario. The data was organized in Pareto graphs to determine the most significant impact per machine and higher call opening demand; then, the data was applied to the probability of failure functions to know which model has the best data behavior and, hence, apply the data to the reliability function R(t) and MTTF.

This article aims to analyze the reliability and the meantime of the machine's flaw that most imply the failures of the production line. So, the maintenance department will be able to direct the efforts and actions to correct the points in order to re-measure the indicators and confirm their evolution or not.

Reliability-Centered Maintenance

Reliability-centric maintenance refers to a maintenance program designed to return the equipment's inherent production capacity [3]. The primary purpose of maintenance is to maintain and improve the reliability and regularity of the production system's operation [4].

Siqueira [5] reports that the RCM incorporates new maintenance and monitoring techniques, as well as absorbs modern statistical optimization methods developed by production engineering. One of the advantage of this system is the establishment of a structured way to select maintenance activities.

The production system has a few failures. So, the reliability and availability of machines and equipment increase the point to be solved. For Xie and colleagues [6], the failures in a regular operation system are random events caused by a sudden increase in stress or human error.

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Key Reliability Indicators and Functions

The time to fail, measured from the time the unit is commissioned to fail, is defined by the equation:

$$F(t) = P(T \leq t) = \int_0^t f(u)du \text{ , } t > 0 \quad (1)$$

The equation that defines the reliability is:

$$R(t) = \frac{n_s(t)}{n_s(t) + n_f(t)} = \frac{n_s(t)}{n_0} \quad (2)$$

The equation for risk is following (the risk is also known as failure rate or risk-rate, and it is associated with the conditions under which the unit is subjected):

$$h(t) = \lim_{\Delta t \to \infty} \frac{R(t) - R(t+\Delta t)}{R(t)\Delta t} = \frac{-R(t)}{R(t)} \quad (3)$$

$$= \frac{f(t)}{R(t)} \text{ , } t \geq 0$$

The meantime to fail:

$$MTTF = E(t) = \int_0^{+\infty} tf(t)dt \quad (4)$$

Methods

According to Fogliatto and Ribeiro [4], the main models used to describe reliability functions are exponential probability distributions, Weibull, gamma, lognormal, and reasonable. In the definitions of reliability analysis, it is necessary to determine which probability distribution best fits the data.

We presented a case study in which the data was collected from a company, and the reliability-centered maintenance technique was applied. We used Minitab v. 17 software for the graphs of the probability functions of some statistical models.

Case Study

The company studies is established in the State of Bahia, Brazil, in an industrial headquarters in Salvador city. This organization is a leader in the northeast region in the production of corn products, snacks, popularly known as “salty snacks”. The factory is comprised of production lines and has approximately 200 employees working directly in production. The production line studied was “salty,” following some definitions that characterize the process for the operation of the line.

<u>Workday</u>: Monday to Saturday from 10 PM to 6 AM; starting on Sunday at 10 PM and stopping on Saturday at 10 PM;

<u>Three work shifts</u>: Night, morning and afternoon;

<u>The line consists of 4 machines</u>;

<u>Work directly in line production</u>: 60 employees and 20 per shift;

<u>The average day of 25 production days per month</u>;

<u>The start of the line production</u>: Sundays in the night shift that starts at 10 PM, and the time is scheduled for 1h to prepare the machines;

<u>Every Tuesday</u>: Service is held at 11AM for the staff, and all employees of the morning shift are released 1h earlier so that they can attend. On Saturdays, the morning shift ends the operation of the line at 1 PM;

<u>On Saturdays</u>: The line is cleaned, so there is no production operation in the afternoon shift.

Table 1 shows the hours in daily hours of each work shift and defines the production operating hours of the line. It is possible to observe that the snack line operates at 19.33h/day.

Table 1. The shifts' workday.

Shift	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Average hours (round/day)
Night	6	7	7	7	7	7	7	6.83
Morning	7	6	7	7	7	7	6	6.67
Evening	7	7	7	7	7	0	0	5.83
Factory	20	20	21	21	21	13	0	19.33

Table 2 presents the data on the meantime between failures of the machine that compromises the snack food production line (hours per month).

Table 2. MTTF (h) of the snack line machine.

	Jan	Feb	Mar	Apr	May	Jun	Jul
Supply Mat	136	11	82	9	11	6	9
Extruder	367	217	22	29	32	35	96
Packager	211	269	420	101	158	124	180
Oven	80	50	30	20	15	14	10

Table 3 provides information on cumulative data on maintenance service order quantities opened each month. Table 4 provides crucial information for directing the actions of the maintenance department, thinking of planning the workload for each available staff-hour.

Table 3. Number of occurrences.

	Jan	Feb	Mar	Apr	May	Jun	Jul
Supply Mat	31	46	28	19	13	15	18
Extruder	39	24	10	25	20	9	20
Packager	115	125	80	93	87	25	30

Table 4 and Figure 2 guide the prioritization of maintenance department actions for the equipment that most affects failures and to plan their workforce, staff-hours regarding the type of maintenance.

Table 4. The calls by maintenance type.

	Jan	Feb	Mar	Apr	May	Jun	Jul
Electrical	15	22	15	19	21	3	2
Mechamical	90	88	60	66	58	20	35
Pneumatic	10	15	5	8	8	2	3
Total	115	125	80	93	87	25	3

Figure 1. Pareto of MTTF of the machine of the snack line.

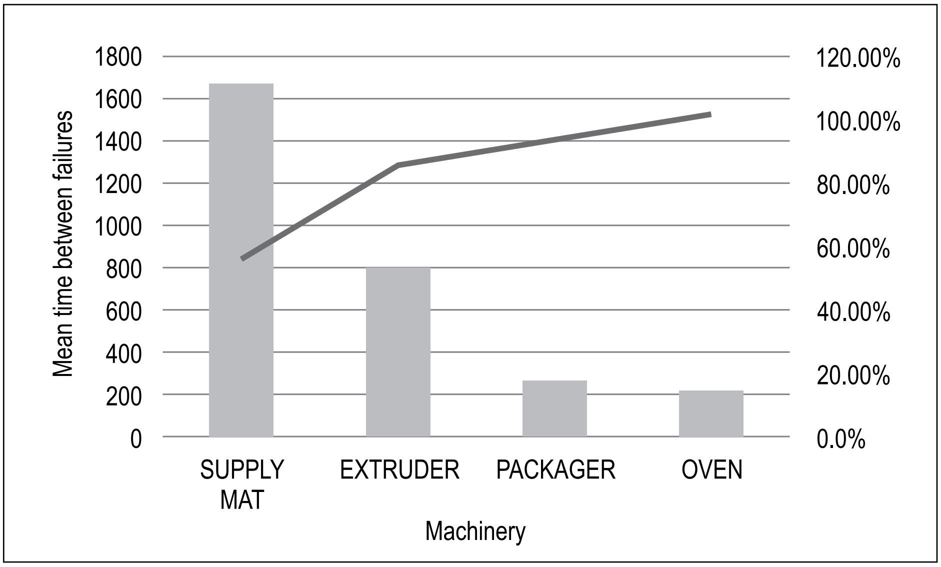
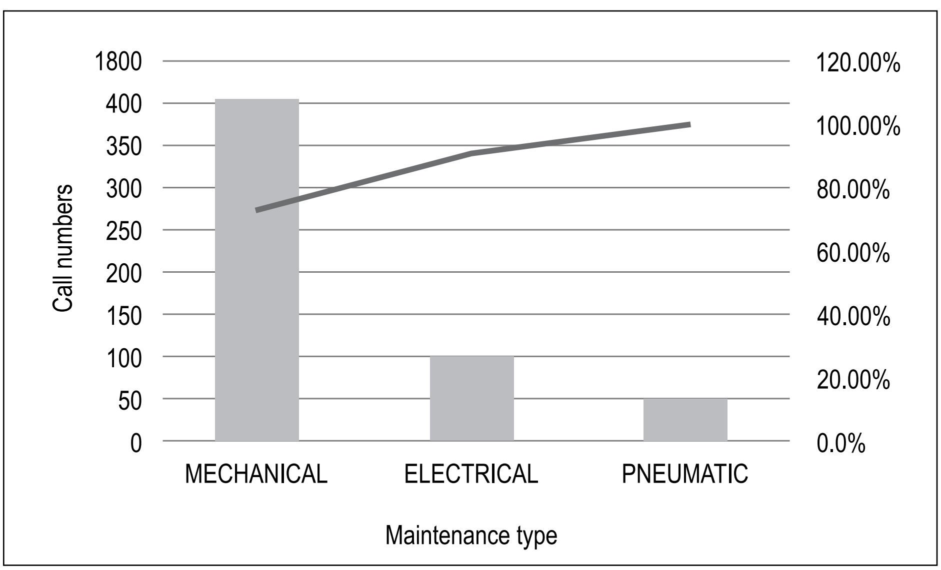


Figure 2. Priority Pareto by maintenance type.



Based on Table 3 and Figure 1, the efforts should be addressed to the packing equipment with the robust performance of the mechanical maintenance team.

Table 5 presents the weekly MTTF (h) of the snack line wrapper due to the analysis of the graphical representation of Figure 1, demonstrating the importance of prioritizing the actions on the wrapper.

By applying the data from Table 5, we get to know the probabilistic model, which presents the best behavior.

For analysis and definition of the model, we used the Anderson-Darling test that serves to verify how well the data follows a distribution. By analyzing the values expressed in Table 6 for the Anderson-Darling test, we found that Lognormal is the probability model that best presents the distribution of data.

Table 5. Weekly MTTF of the wrapper.

Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**
40	35	45	51	40
Week 6	Week 7	Week 8	Week 9	Week 10
68	67	67	68	70
Week 11	Week 12	Week 13	Week 14	Week 15
130	100	120	50	20
Week 16	Week 17	Week 18	Week 19	Week 20
20	11	35	46	48
Week 21	Week 22	Week 23	Week 24	Week 25
30	35	37	40	13
Week 26	Week 27	Week 28	Week 29	Week 30
39	25	28	31	30
Week 31				
27				

The probability presented in the graphs (Figures 1 and 2) allowed the hypothesis test for suitability to a given distribution and made the analysis of the corresponding ρ value necessary. If the value of ρ is less than or equal to α, which is the significance level (α = 0.05), then the null hypothesis that the data followed the distribution is rejected. Minitab software for some cases does not always converge mathematically, so the Anderson-Darling test is used to calculate the p-value.

Based on the Anderson-Darling statistic values expressed in Table 6 and the analysis of the Figure 3, we verified that the lognormal distribution presents the best approximation for the data. So lognormal is the distribution that represented the best model for the data.

Defining the probability distribution as lognormal, we apply the values to the reliability model using Eq. (5) to μ=3.70168 and σ=0.56858.

$$R(t) = 1 - \sigma\left(\frac{\ln(t) - \mu}{\sigma}\right) \qquad (5)$$

Therefore, considering t = 100 hours, we have R(t) = 0.47, i.e., for every 100 hours, so we have a probability of 47 hours of the wrapper not breaking.

We calculated the meantime to fail, as Eq. (6) to μ = 3.70168 and σ = 0.56858, resulting MTTF = 47.62 hours.

$$\text{MTTF} = e^{\mu + 0{,}5.\ \sigma^2} \qquad (6)$$

As the working day of the snack line is 19.33 hours, we have an MTTF corresponding to 2.5 days.

Conclusions

The present study sought through the technical application of the concepts of reliability and the use of real data, to support the national industry and demonstrate the importance of integration between companies and universities in order to develop technology and give durability and capability to industrial processes.

The machine analyzed in the packaging process (wrapper) had a reliability of 47%, which is very low, as well as an MTTF indicator of 2.5 days. The machine is operated for three shifts for six days,

Figure 3. Probability chart for failure.

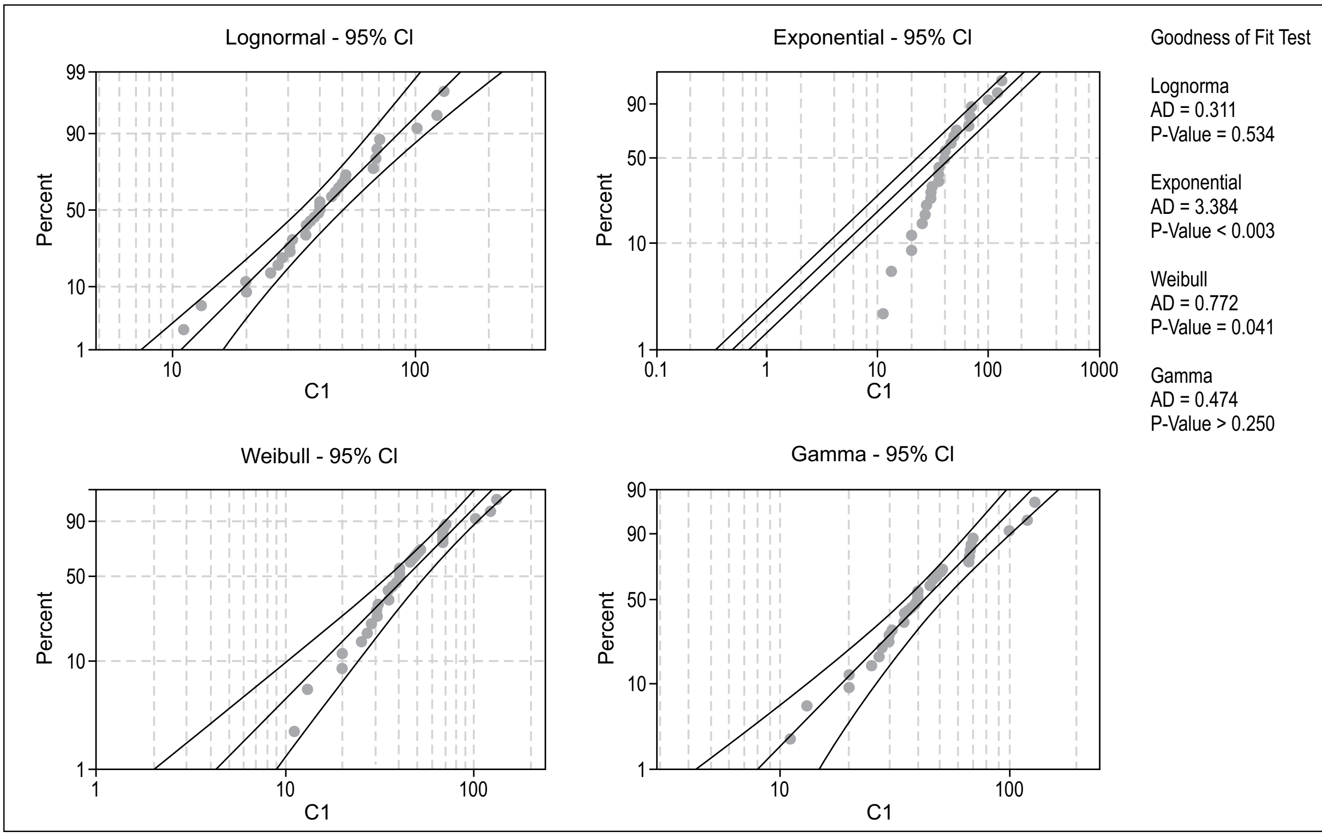


Table 6. Anderson-Darling statistic values for various distributions.

Distribution	AD
Normal	1.512
Box-Cox Transformation	0.311
Lognormal	0.311
3-Parameter Lognormal	0.305
Exponential	3.389
2-Parameter Exponential	1.502
Weibull	0.772
3-Parameter Weibull	0.497
Smallest Extreme Value	2.851
Largest Extreme Value	0.448
Gamma	0.474
3-Parameter Gamma	0.540
Logistic	0.976
Log-logistic	0.235
3-Parameter Log-logistic	0.233
Johnson Transformation	0.183

meaning that there will be probably two possible occurrences of mechanical failure in a working week.

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