Digital Innovations & Contemporary Research in SCIENCE, ENGINEERING & TECHNOLOGY
Vol. 11. No. 4, December, 2023

Article Citation Format
Ikechukwu John Ezemenike, Harold Ugochukwu Nwosu, & Matthew Uzoma Shadrach (2023): Reliability Analysis for a Systems with Multiple Failure Modes and Subsystems: The Case of a Nigerian Fabrication Company.
Journal of Digital Innovations & Contemporary Research in Science, Engineering & Technology. Vol. 11, No. 3. Pp 31-46
dx.doi.org/10.22624/AIMS/DIGITAL/V11N4P3.
www.isteams.net/digitaljournal.

Article Progress Time Stamps

Article Type: Research Article
Manuscript Received: 14th November, 2023
Review Type: Blind Peer
Final Acceptance: 4th December, 2023

Reliability Analysis for a Systems with Multiple Failure Modes and Subsystems: The Case of a Nigerian Fabrication Company

Ikechukwu John Ezemenike, Harold Ugochukwu Nwosu, & Matthew Uzoma Shadrach
Department of Mechanical Engineering
Faculty of Engineering
School of Graduate Studies
University of Port Harcourt
Port Harcourt, Nigeria
E-mails: ezemenikejohn2002@yahoo.com, harold.nwosu@uniport.edu.ng; shadrack.uzoma@uniport.edu.ng

ABSTRACT

The reliability of the equipment, the working environment, the effectiveness of maintenance, the operation techniques, the technical skills of Machinist, etc. all affect how well machining equipment performs. The consequences of equipment failure become more catastrophic as the size and variety of fabrication equipment keep growing. In order to locate the system's shortcomings and identify the parts or units with low reliability for the specified designed performance, reliability analysis is necessary. This research discusses the reliability analysis of the lathe machine. Four subsystems of the lathe machine are identified and root cause analysis was carried out for all subsystems failure modes. Minitab 19 was employed to estimate the parameters settings of certain probability distributions, which includes the Weibull, Exponential, Loglogistic and Lognormal distributions. According to findings of the analysis, the belt drive subsystem is critical to the reliability of the Lathe machine. The study also demonstrates how reliability analysis is valuable in determining inspection periods.

Keywords: Reliability Analysis, Root Cause Analysis, Lathe Machine, Reliability importance, Minitab19

1. INTRODUCTION

Reliable, cost-effective production has become an increasingly important issue in the recent competitive business world. According to the literature (Maleki & Yang, 2017; Tsang et al., 1999), although frequent system maintenance was performed to improve the reliability, they might result in high operational costs. Reliability-centered maintenance (RCM) determines the type of maintenance tactics to be applied to an asset for preserving system function. While it answers the question of "What type of maintenance action needs to be taken?" the issue of when to perform the recommended maintenance action that will produce the best results remains to be addressed.

Taking a longer-term perspective, we have to make decisions on asset replacement in the best interests of the organization, and also to determine the resource requirements of asset management that will meet the business needs of organizations cost-effectively. There are numerous subsystems in a mine production system. To make the system lucrative and operationally viable, each subsystem must be optimized in respect to the others. The system's performance capabilities, availability, dependability, and maintainability, as well as its ability to meet expectations, are the major factors that affect how effective a piece Machining equipment is. Since the middle of the 1980s, reliability analysis approaches have increasingly become regarded as standard tools for the planning and management of autonomous and complicated production systems (Barabady and Kumar, 2007). Since failures cannot be totally avoided, it is crucial to reduce both their likelihood of happening and their effects when they do (Blischke and Murthy, 2003) An efficient maintenance program is necessary to maintain the specified availability, reliability and maintainability characteristics as well as to achieve desired performance. Low maintenance costs are a hallmark of successful upkeep. All production and manufacturing facilities have running expenses that make up a significant portion of their total costs.

Depending on the industry, these expenses can range from 15% to 60% of the price of the products produced (Mobley, 2002). The unscheduled system stops for unscheduled system or component repairs account for a sizable portion of the mining system's operational costs. Preventive maintenance is therefore commonly regarded as a successful method for minimizing system failure rates and thereby reducing total maintenance costs (Okogbaa and Peng, 1996). Planned maintenance's major objective is to stop equipment failure before it really happens. Equipment checks, partial or total overhauls at predetermined intervals, oil changes, lubrication, and other maintenance procedures are examples of preventive maintenance tasks. High reliability is ideal from a business standpoint because it lowers system expenses for maintenance. The mine production system's important and sensitive subsystems, which have a significant impact on system failure, have been identified with the aid of reliability analysis. In order to optimize the performance of equipment and guarantee that equipment is available for production in accordance with schedules available in the production planning, reliability must be a top priority.

The primary goals of this research are: to increase understanding of the nature of the failure patterns of the lathe machine in the fabrication company, to estimate the reliability and availability characteristics of the lathe machine in precise quantitative terms and to identify the critical subsystems of the lathe machine that require further improvement through effective maintenance policies to improve the overall reliability.

Concepts of the Reliability Analysis Process

The process to analyze the reliability of repairable system with applicable tests is presented in Figure 1. It is employed herein as a framework for the analysis of the failure and repair data of the lathe machine and displays a comprehensive sequence for model identification. There are several sources of data in machining plants that are pertinent to the reliability modeling of lathe machine components, including operating and repair data, data from sensors, etc. (Hall and Daneshmend, 2003). Finding failures with major consequences is the first stage in the analysis of such data. The presumed existence of a renewable process for the TBF for each subsystem is validated after the data has been collected, sorted, and classified. The trend test and the correlation test are two often used techniques to verify this assumption, and they are both explained with concrete examples by (Raju and Govinda, 2018).

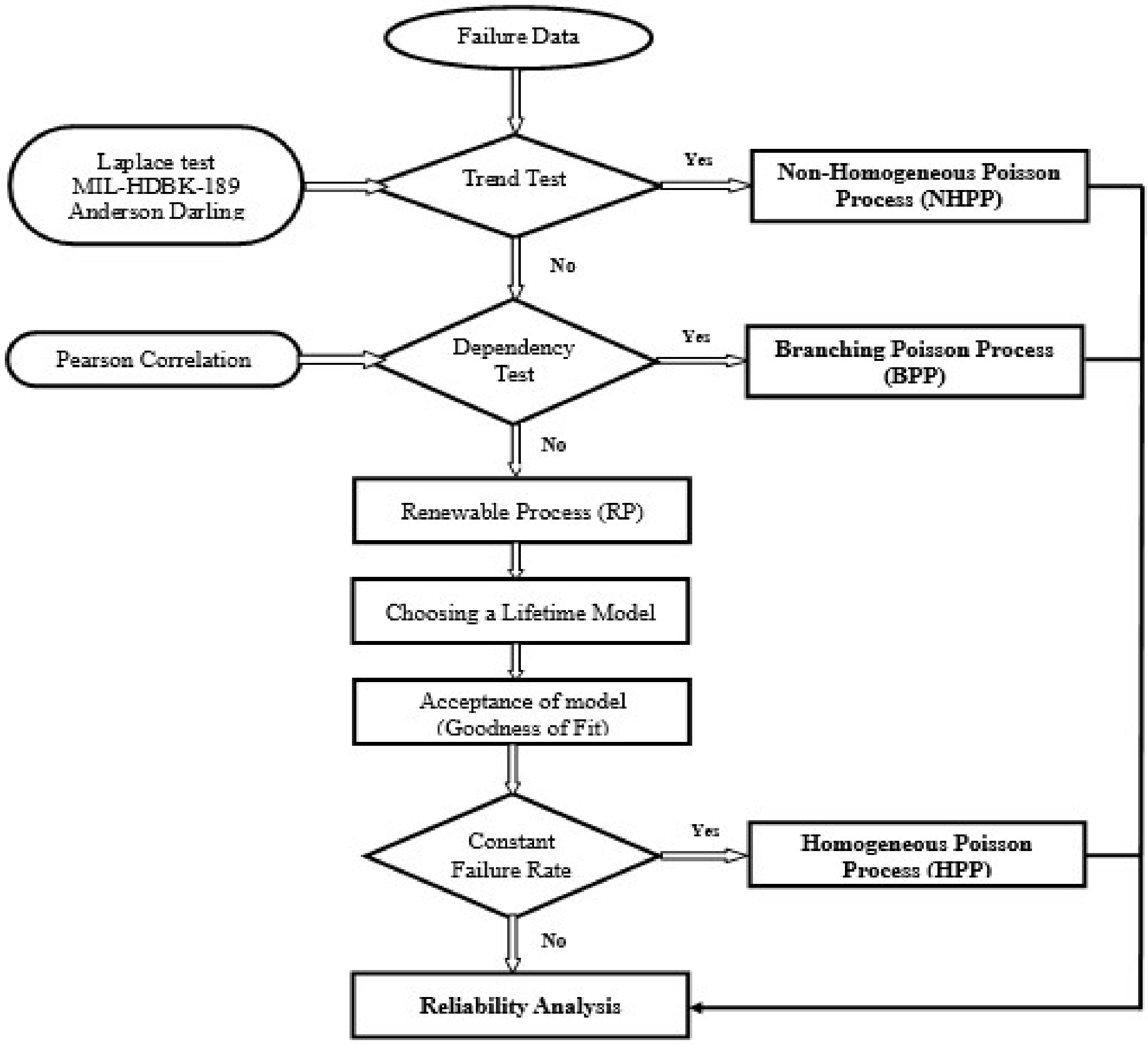

Figure 1: Reliability analysis processes.

In the model validation phase of the reliability analysis process for reparable system, the first step is to verify if the independence hypothesis of the failure data is respected. If the hypothesis validation is not confirmed then classical statistical techniques cannot be applied and it is necessary to use the non-homogeneous Poisson process (Ascher and Feingold, 1984). The methods used to fit an independent and identically distributed function are significantly distinct from those used to fit an NHPP to dynamic failure data. The NHPP model, based on the power law process, has been used most frequently as a functional form for repairable systems (Rigdon and Basu, 2000) Independent data implies that there is no trend: each failure is independent of the previous or the next failure. Identical distributions indicate that data come from the same probability distribution. If the process is free of trends, the application of the dependency test will specify whether the data follow a renewal process or a branching Poisson process. The detection and the analysis of dependency can be realized with the correlation coefficient.

If there is acceptance of the hypothesis which accepts the existence of correlation between data, it is possible to model the failures by the branching Poisson process.

The idea of important measure can be used to determine the criticality of each subsystem after locating its reliability features. Component importance analysis, according to Besson and Andrews (Beeson and Andres, 2003) is a crucial step in the system reliability assessment process. This step identifies a system's weakest points and suggests adjustments that will strengthen the system's reliability.

2. METHODOLOGY

A system is made up of a number of components or subsystems that are often conceptually coupled to one another either in series or parallel. The system's configuration and the dependability of its subsystems determine how reliable the system is. It is preferable to divide the overall system into subsystems before examining the failure data so that the failures can be organized. The result of the root cause analysis 'failure, mode, effect and cause (FMEC)' for selected a lathe machine is presented in Table 1. For more details on root cause analysis, refer to Braaksma et al. (2013).

Failure Data Collection and Sorting

These include gathering data from various late machine data sources, classifying the data needed for assessment, and arranging the data into the format needed for analysis (e.g., TBF, TTR, frequency, overall hours of breakdown, total hours of repair, etc.). The information used in recent studies was gathered over a year. The data used for this research is based on information recorded by technicians in maintenance intervention reports, a set of values for failure times was compiled. All of the data in this case corresponds to failure events. It should also be noted that the records were associated with all failure modes of component considered.

Trend and Correlation Test

Three tests shall be employed to test for trend in the failure data that have been sorted and analysed. They are; the Laplace, MIL-HDBK 189 and Anderson Darling tests. The Spearman Correlation test shall be used to test for independency of inter-arrival time of failures. These tests shall be carried out using Minitab 19 software. After carrying out trend and Correlation tests and establishing suitable models suitable for failure data, Minitab 19 software will also be employed in fitting failure times to lifetime distribution model. Based on the Goodness of Fit, a probability distribution will be selected for different subsystems with estimated parameters of the model. With these estimated model parameters, the PDF, the survival function (reliability at specific times), hazard function, etc., shall be estimated for all subsystems.

Because of the functionality of these subsystems, the lathe machine can only function properly when every subsystem is performing as intended. The reliability of the entire system can be computed using Equation (1).

$$R_{sys} = \prod_{k=1}^{4} R_k \quad (1)$$

The reliability importance, C, of subsystem k in a system of n subsystem is given by Equation (2).

$$C_k = \frac{\partial R_{sys}(t)}{\partial R_k(t)} \quad (2)$$

Where $R_{sys}(t)$ and $R_k(t)$ are the system reliability and the subsystem reliability respectively.

Table 1. Subsystem Components, Failure Mode Effect and Cause (FMEC) of Lathe Machine.

COMPONENT	COMPONENT FUNCTION	MODES	FAILURE EFFECTS
1 Motor	Convert electrical energy to mechanical energy	1.1 Overheating failures	Voltage unbalances load which leads to overheating and decreased efficiency.
		1.2 Power supply anomalies	Separation of grease and breakdown of oil causing bearing failure.
2 Bearing	Supporting and aligning other parts of the lathe machine	2.1 Indentation	Denting on ball bearing
		2.2 Wear	Premature failure of contact surfaces.
		2.3 Collapse	Bearing breakage and uneven distribution of load Bearing will not run.
3 Gear Box	Provide speed and torque conversions from a rotating power source	3.1 Wear	Bearing seized. Gear tooth eroded by wear.
		3.2 surface fatigue failure	Formation of pitting. Gear tooth may break.
		3.3 Breakage	Cracking of vital components in gear.
4 Belt Drive	Power transmission between shafts	4.1 Belt slip	Wear and heat generated with reduced belt life.
		4.2 Belt fatigue	Broken belt.
		4.3 Pulley misalignment	Belt failure.

3. RESULTS AND DISCUSSION

This section outlines results from the proposed reliability analysis. This section is outlined according to the procedure of the analysis. This section is divided into three distinct subsections namely: trend test for inter-arrival times, dependency test for failure times and lifetime distribution model. The failure data distribution by subsystems as collected from the CMMS is shown in Figure 2. From Figure 2, the belt drive system has over 50% of occurrence with insignificant difference found for the motor, bearing and gear box components.

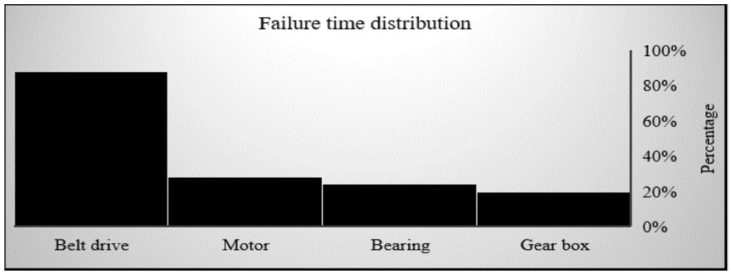

Figure 2: Pareto Diagram for Failure Times.

Trend Test for Failure Inter-Arrival Time

Failure data collected for the system as presented in Appendix A are used for this analysis. The data from the database are first subjected to a trend test. The Laplace test, the Military Handbook trend test (MIL-HDBK-189) and the Anderson-Darling test are used. The test is carried out using Minitab 19. The test is carried out for each subsystem and their result is tabulated in Table 2. The result for all three tests in all subsystems is consistent.

For the motor subsystem, the p-value for each test is 0.617, 0.898, 0.995 corresponding to the Laplace, MIL-HDBK-189 and Anderson-Darling test respectively. This is shown in Table 4.2 For all three-trend test, the p-value are far greater than the α-value of 0.05 which indicates that the failure times for the Motor subsystem do not exhibit trend. The result between the three tests is consistent which indicates it has failed the trend test. The bearing subsystem have p-values of 0.851, 0.994 and 1.00 for the Laplace, MIL-HDBK-189 and Anderson-Darling trend test respectively, as shown in Table 2. The p-values for the trend tests for the bearing subsystem are greater than the α-value of 0.05 which means there is no significant evidence of trend in failure times for bearing Subsystem. As seen from the motor subsystem, there is no trend in time between failure (TBF) data and the result is consistent with all three tests.

The trend tests with the TBF data from the gear box subsystem produces p-values of 0.860, 0.647 and 0.942 corresponding to the Laplace, MIL-HDBK-189 and Anderson-Darling trend tests respectively, as shown in Table 2. There is a high consistency between the result of all the three tests as the p-values for all tests are greater the α-value of 0.05 which means there is no significant evidence of trend in the TBF data of the gear box components.

Table 2. Trend Test for Failure Times of Machine Subsystems.

Components		MIL-Hdbk-189	Laplace's	Anderson-Darling
Motor	Test Statistic	25.88	0.14	0.12
	P-Value	0.940	0.890	1.000
	DF	26	-	-
Bearing	Test Statistic	20.14	0.01	0.12
	P-Value	0.851	0.994	1.000
	DF	22	-	-
Gear Box	Test Statistic	15.84	-0.02	0.20
	P-Value	0.793	0.983	0.990
	DF	18	-	-
Belt Drive	Test Statistic	83.17	-0.01	0.07
	P-Value	0.867	0.882	0.999
	DF	86	-	-

The trend test carried out for the belt drive subsystem is shown in Table 4.2. The three tests produce p-values of 0.821, 0.992 and 1.000 corresponding to the Laplace, MIL-HDBK-189 and Anderson-Darling trend tests respectively. There is high consistency between results of the three tests. These p-values are greater than the α-value of 0.05 which indicates that that is no significant evidence that that the failure times for the belt drive subsystem exhibits trend.

Dependency Test

The Spearman correlation test was carried out on failure data for all subsystems and the result of the correlation test between the cumulative failure and time between failure for the four subsystems components are shown in Table 3.

Table 1: Result of Dependency test between the cumulative failure and time between failure (TBF).

Components	Correlation	95% CI for ρ	P-Value
Motor	-0.027	(-0.549, 0.511)	0.928
Bearing	-0.020	(-0.560, 0.587)	0.950
Gear Box	0.067	(-0.587, 0.669)	0.854
Belt Drive	-0.024	(-0.319, 0.274)	0.875

For motor subsystem, the correlation coefficient of -0.027 and p-value of 0.928 indicate no significant evidence of correlation between the inter-arrival time of failure. This means the failure times are independent of previous failures. The correlation test carried out on bearing subsystem is also highlighted in Table 3. The result shows correlation coefficient of -0.020 with p-value of 0.950 which indicates there is no significant evidence of correlation between the inter-arrival time of failures. The failure times for the bearing subsystem are independent and identical. A correlation coefficient of 0.067 and a p-value of 0.854 was obtained from the correlation test for Gear box subsystem. This result indicates no correlation between the inter-arrival time of failures for the gear box subsystem. It is also useful to conclude that the inter-arrival time of failure for the gear box subsystem are independent and identical. For belt drive subsystem, the correlation coefficient of -0.024 and p-value of 0.875 indicates no significant evidence of correlation between the inter-arrival time of failure. This means the failure times are independent of previous failures and can be modeled as a renewable process (Independent and identically distributed).

The correlation test carried out for all subsystems shows that data of inter-arrival time are statistically independent and identical and can be modelled as a renewable process (RP). After testing for trend and dependency, the next step in the reliability analysis is to fit the data to a distribution. The mean time between failure (MTBF) in hours for the four subsystems were also generated as 482.3, 594.3, 655.7 and 166 for the motor, bearing, gear box and the belt drive subsystems respectively. The MTBF for all the subsystem is presented in Figure 3. The bearing and gear box subsystems have very high MTBF as compared to the MTBF of the belt drive subsystem and fairly higher for the motor sub system.

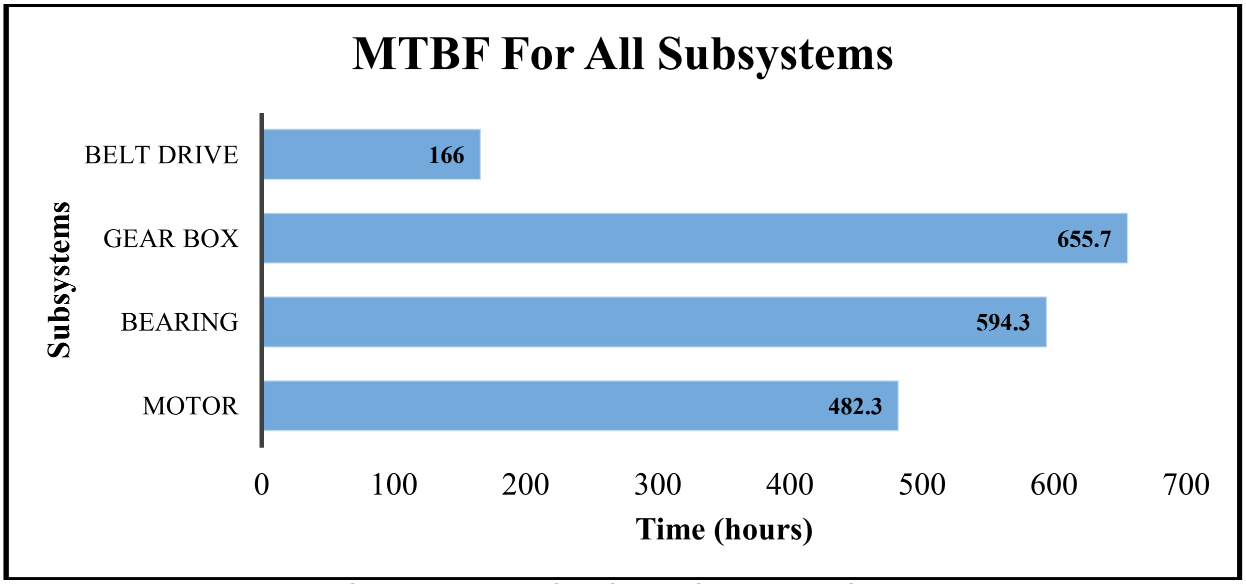

Figure 3: Mean time Before failure for the Four Subsystems.

Analysis of Lifetime distribution Models

The trend test results for all subsystems shows that the systems cannot be modelled with non-Homogenous poison process (Raju et al., 2021). The dependency test for all four subsystems also shows that the inter-arrival time of failures are independent with previous failure times and as a result the Poison Branching Process is not suitable to model the subsystems. The problem of prescribing the right probability distribution model for the failure of subsystem arises. To fit the lifetime data to a distribution, Minitab is used to fit the failure data for all the four subsystems to four distributions namely: The 3 parameter Weibull, the 2 parameter Exponential, the Loglogistic and the Lognormal model are used to fit the failure data. The results are shown in Figures 4-7. Figures 4-7 show the probability plot of the distributions and how the failure data from the four subsystems fit the distributions.

The result of fit generated in Minitab for the motor subsystem are plotted in Figure 4. The correlation coefficient for the four different distributions is presented in Figure 8. From Figure 4, the 3 parameters have the best fit as compared to the other three distributions. The 2-parameter exponential distribution cannot model the failure data because of outlier in data. Also, from Figure 8, 3 parameters Weibull have the highest correlation coefficient of 0.992 as compared to 0.888 and 0.983 for the Loglogistic and Lognormal distribution respectively. Figure 5 shows the fit of lifetime failure data for the bearing subsystem. From visual inspection the 3 parameter Weibull have the best fit as compared to the 2-parameter exponential, Loglogistic and Lognormal distributions. The correlation coefficients for the fit as presented in Figure 8 are 0.994, 0.942, 0.988 corresponding to the 3 parameter Weibull, the Loglogistic and the Lognormal distributions. Again, the exponential distribution failed to fit the failure data because of outliers as shown in Figure 5. The 3 parameter Weibull have outperformed the other distributions.

The Gear box subsystem failure data is best fitted with the 3 parameter Weibull distribution as compared to the 2 parameter Exponential, the Loglogistic and the Lognormal distributions. This is shown in Figure 6. The Lognormal distribution is a better fit as compared to the 2-parameter exponential and the Loglogistic distributions. From Figure 6, the exponential distribution failed to fit the data because of outliers I data. Figure 8 shows the correlation coefficients of the fits for the selected distributions as 0.996, 0.955 and 0.991 corresponding to the 3 parameter Weibull, the Loglogistic and the Lognormal distributions. The 3 parameter Weibull have the highest correlation as compared with the other three distributions which validate the visual results from the plot.

Figure 7 shows Weibull distribution is the best fitted to the lifetime failure data of the belt drive subsystem as compared to the 2 parameter Exponential, the Loglogistic and the Lognormal distributions. The correlation of the fits for the selected distributions are highlighted in Figure 8 as 0.99, 0.919 and 0.967 corresponding to the 3 parameter Weibull, the Loglogistic and the Lognormal distributions. The 3 parameter Weibull have the highest correlation as compared with the other three distributions which is consistent with the visual results from the plot. For all subsystems, the 3 parameter Weibull have shown to be the best fit with correlation coefficient ≥ 0.990 (which is a good value in reliability studies) for all subsystems and as such, the four subsystems will be modelled using the 3 parameter Weibull Distribution. The distribution overview plot which includes details of the probability density function, survival function, the hazard function and the fitting of the life data to the 3 parameter Weibull distribution for all four subsystems are presented in Appendix.

Using Minitab 19 software, the theoretical reliabilities for each of the four subsystems at various time periods were evaluated using parameters estimated by Minitab 19 for the Weibull Distribution. The reliability of the lathe machine component by component at selected time intervals are presented in Table 4. Table 4 shows that as mission time grows, the reliability of the lathe machine and its components reduces. In addition, it can be observed that there is only a likelihood of 74.5% that the lathe machine won't fail for 600 hours of operation or 91.6% that the motor system won't fail for 600 hours of operation.

The reliability importance of the various components of the lathe machine, as determined by Equation (2), is depicted in Figure 9. It is discovered that there is a significant difference in reliability importance for belt drive system as compared to the motor, bearing and gearbox systems. To improve the reliability of the lathe machine, most efforts should be made in in enhancing the reliability of the belt drive system since it most critical in determining the overall Reliability of the lathe machine.

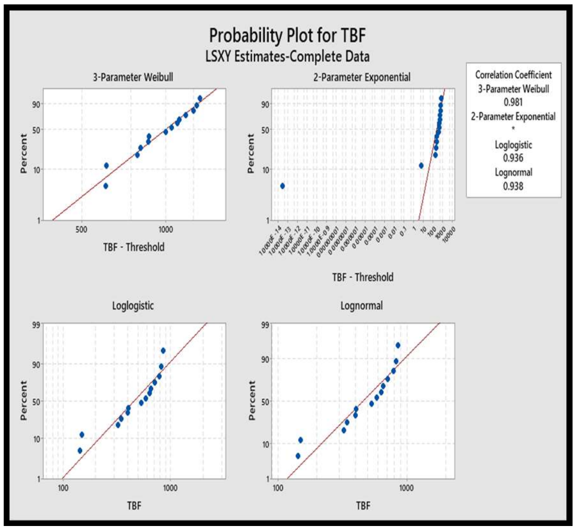

Figure 4: Distribution ID plot for Motor Subsystem.

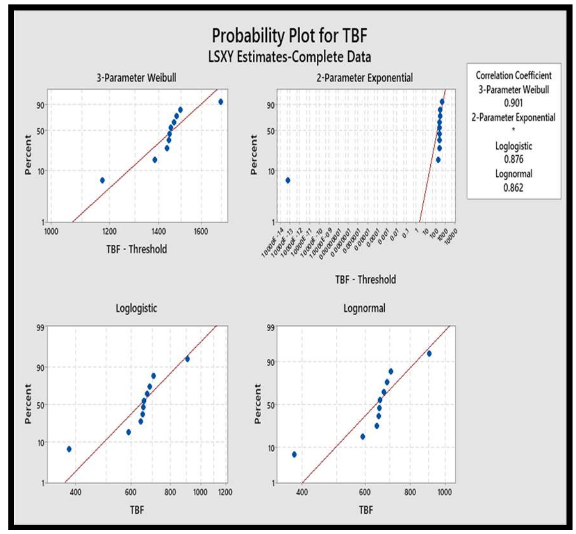

Figure 5: Distribution ID plot for Bearing Subsystem.

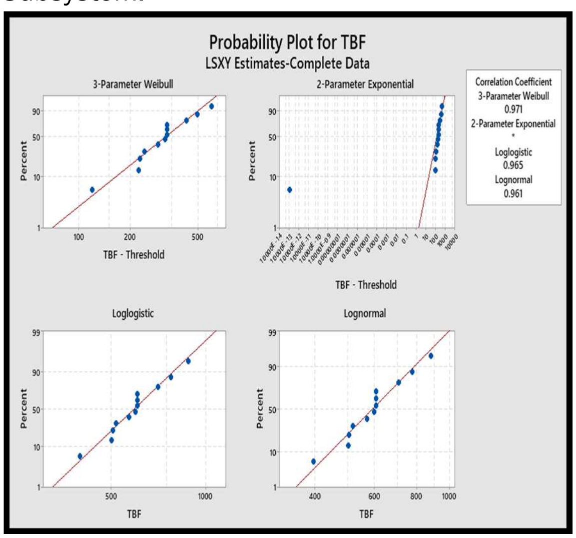

Figure 6: Distribution ID plot for Gear Box Subsystem

.

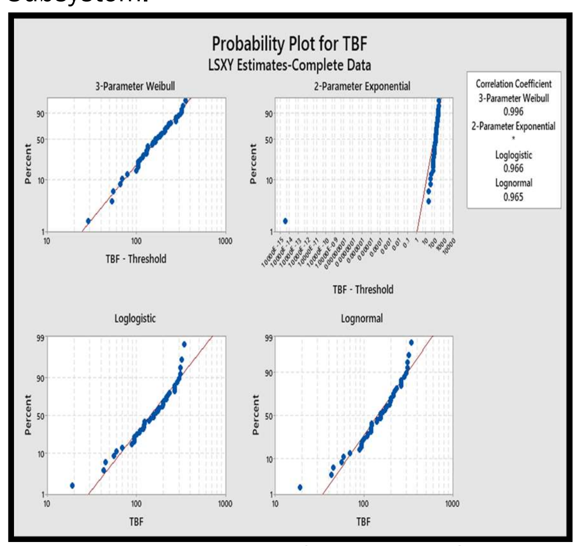

Figure 7: Distribution ID plot for Belt Drive Subsystem

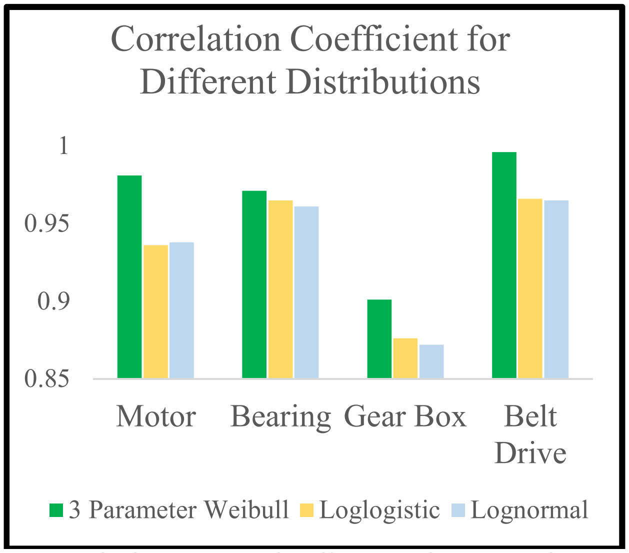

Figure 8: Correlation Coefficient of Data Fit for the different Subsystem.

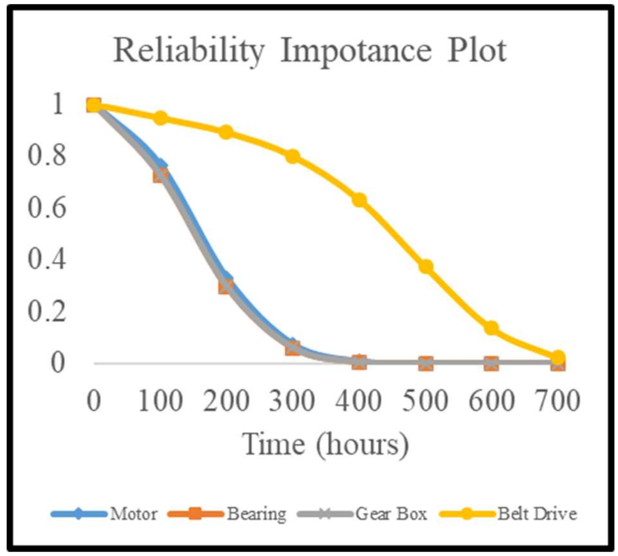

Figure 9: Reliability Importance Plot for Different Subsystem.

Table 4. Reliability of lathe machine and subsystems

Time (hrs)	Motor	Bearing	Gear Box	Belt Drive	Lathe
0	1.000	1.000	1.000	1.000	1.000
100	0.948	1.000	0.999	0.766	0.726
200	0.895	1.000	0.996	0.332	0.296
300	0.811	1.000	0.987	0.075	0.060
400	0.693	0.953	0.957	0.008	0.005
500	0.547	0.780	0.877	0.000	0.000
600	0.388	0.501	0.695	0.000	0.000
700	0.241	0.233	0.391	0.000	0.000

It is also important to establish the time the various subsystem of the lathe machine to achieves certain reliability. Table 5 presents estimated time subsystems of the lathe machine achieve reliability of $R = 0.90$, $R = 0.80$, $R = 0.70$. To achieve 80% reliability, the belt drive system inspection and maintenance action must be carried out before 92 hours because, after 92 hours the probability that the belt drive system will not fail will go below 80%. Because cost information wasn't available, the reliability-based time interval was estimated only using the operating characteristics of crusher plant number 3.

Given the safety consequences, cost-benefit assessment and type of fault, the maintenance intervals for the various reliability levels, given in Table 5 may be utilized for inspection, condition tracking, repair, or replacement, service. The time interval for inspection for reliability of 90% of the belt drive system is too close for practicability. The fabrication company should adopt the maintenance interval recommended for a reliability of 80% for a start, then, after observing the cost-saving benefits, the machine's operational efficiency and safety, could be changed to reflect a greater reliability value.

Table 5. Reliability based maintenance inspection intervals for Different Subsystems.

Subsystems	RCM inspection interval for different reliability settings		
	0.9	0.8	0.7
Motor	192	310	394
Bearing	440	491	531
Gear Box	479	551	598
Belt Drive	62	92	115

3. CONCLUSION

In order to maximize production, reliability analysis studies should constitute a crucial component of engineering management. The most crucial actions that must be taken right away to increase the Reliability of mining equipment are to identify and eliminate the causes of issues in all phases of the life cycle, including planning, design, Fabrication and maintenance, as well as to quantitatively assess the reliability model on the basis of failure past event. The case studies demonstrates that belt drive subsystems are crucial from a reliability standpoint. The belt drive system is crucial in determining how reliable the lathe machine will be, thus if the system has to be enhanced, efforts should initially be focused on increasing its reliability. The study demonstrates the value of reliability analysis in determining preventive maintenance schedules.

REFERENCES

[1] Ascher, H. and Feingold, H. (1984). Repairable system reliability. Dekker, New York.
[2] Barabadi, J. and Kumar, U. (2007). Reliability analysis of mining equipment: A case study of a crushing plant at Jajarm Bauxite Mine in Iran. Reliability Engineering and System Safety, 93, 647–653.
[3] Beeson, S. and Andres, J. D. (2003). Importance measures for non-coherent-system analysis. IEEE Trans, 52(3), 301–310.
[4] Blischke, W. R. and Murthy, D. N. (2003). Case studies in reliability and maintenance. Wiley, USA.
[5] Braaksma, A. J., Klingenberg, W. and Veldman, J. (2013). Failure mode and effect analysis in asset maintenance: A multiple case study in process industry. Int'l Journal of Production Research, 51(4), 1055-1071.
[6] Hall, R. A. and Daneshmend, L. K. (2003). Reliability modeling of surface mining equipment: data gathering and analysis methodologies. Int J Surf Min Reclam Environ, 17(3), 139–55.
[7] Maleki, H. and Yang, Y. (2017). An uncertain programming model for preventive maintenance scheduling. Grey Systems: Theory and Application, 7(1), 111-122. doi: http://doi.org/10.1108/GS-07-2016-0015
[8] Mobley, R. K. (2002). An introduction to predictive maintenance. Elsevier Science, USA.
[9] Okogbaa, O. G. and Peng, X. (1996). Methodology for preventive maintenance analysis under transient response. In: Proceedings of the annual reliability and maintainability symposium, USA, 335–40.

[10] Raju, J. B., Govinda, R. M. and Murthy, C. S. (2018). Reliability analysis and failure rate evaluation of load haul dump machine using Weibull distribution analysis. Journal of Mathematical Modelling of Engineering Problems, 5(2), 116-122.

[11] Rigdon, S. E. and Basu, A. P. (2000). Statistical methods for the reliability of repairable systems. Wiley, USA.

APPENDIX
Distribution Overview Plot

The Distribution Overview plot of the four subsystems using the 3 parameter Weibull distribution is shown in Figure A.1-A.4.

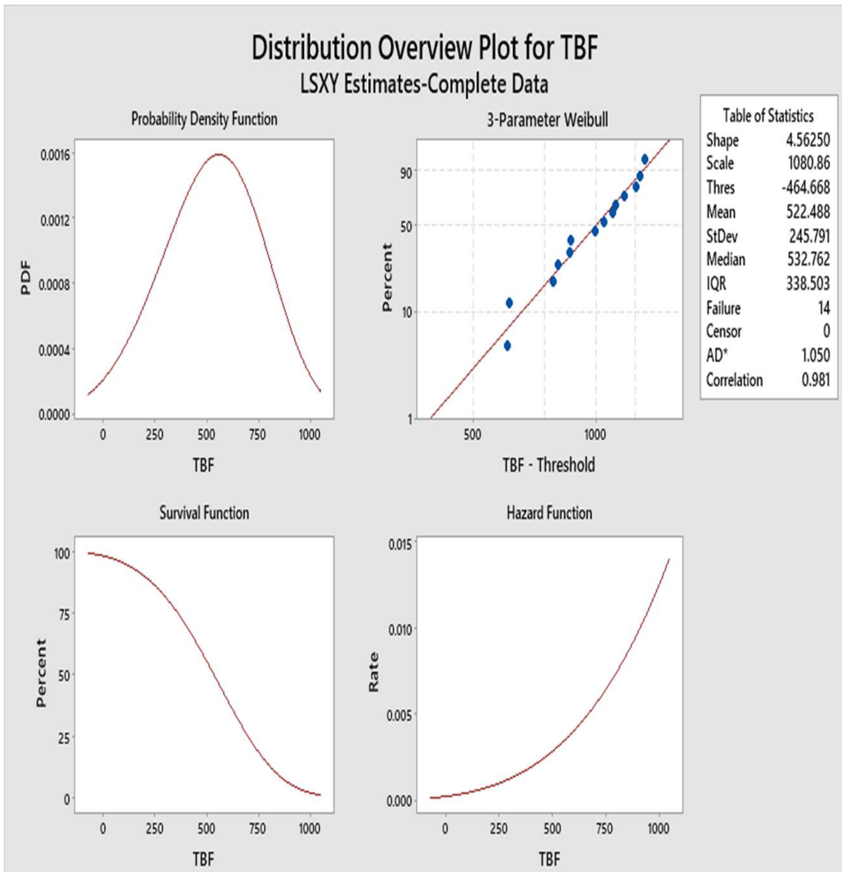

Figure A.1: Probability Overview Plot for the Motor Subsystem

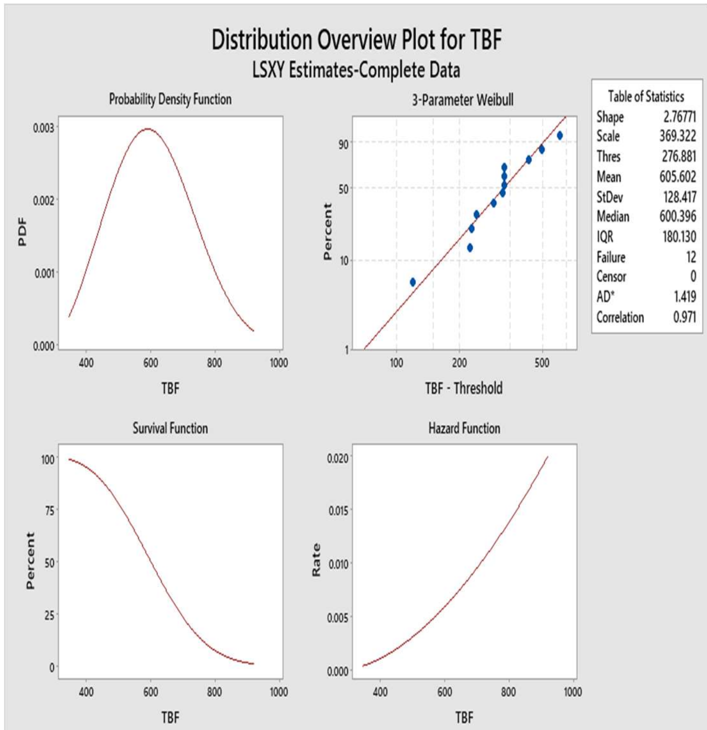

Figure A.2: Probability Overview Plot for the Bearing Subsystem

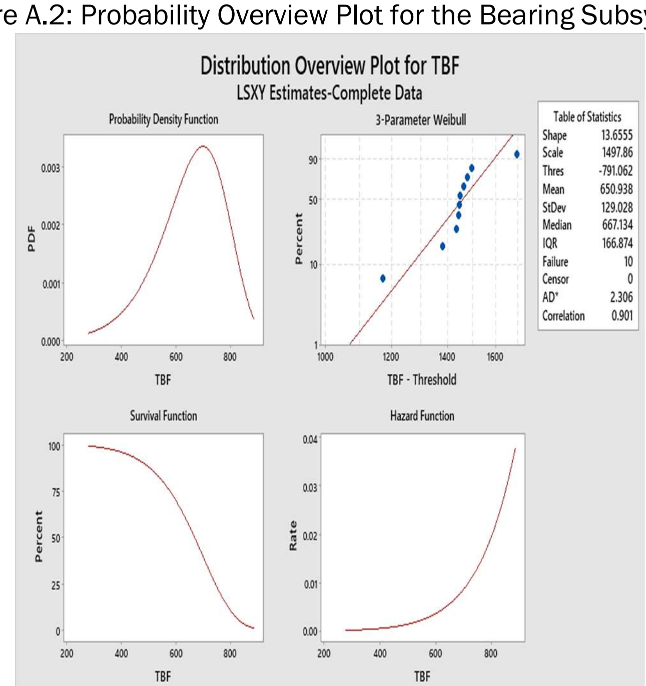

Figure A.3: Probability Overview Plot for the Gear Box Subsystem

Digital Innovations
& Contemporary Research in SCIENCE, ENGINEERING & TECHNOLOGY
Vol. 11. No. 4, December, 2023

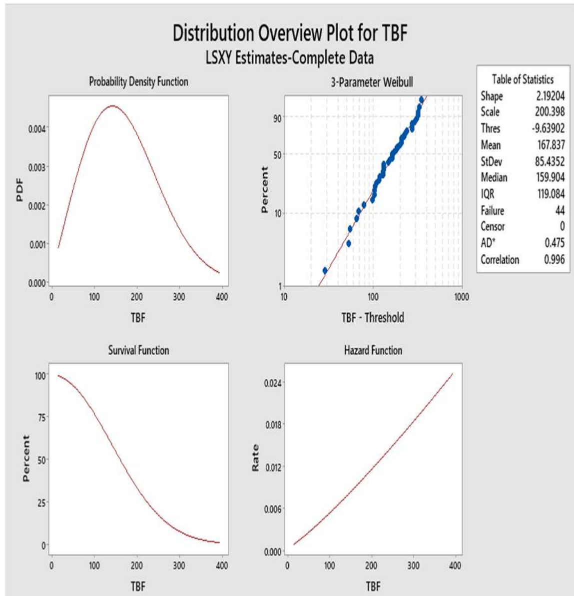

Figure A.4: Probability Overview Plot for the Belt Drive Subsystem