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ANALYSIS OF THE EFFECT OF FABRICATION FAILURE FACTORS AND OPERATIONAL FAILURE FACTORS ON EQUIPMENT RELIABILITY MEDIATED BY MAINTENANCE TECHNOLOGY 4.0 WITH THE USE OF SEM (STRUCTURAL EQUATION MODELLING) METHODS (CASE STUDY OF GENSET PRODUCTS AT PT. XYZ)

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Abstract:
This study aims to analyze the effect of fabrication and operational failure factors on equipment reliability. In addition, this study also examines the impact of fabrication and operational failure factors on Maintenance Technology 4.0 and the impact of Maintenance Technology 4.0 on equipment reliability. This quantitative research was conducted at the genset product of PT XYZ. The sample of this research is the technicians of PT XYZ spread in branches throughout Indonesia, who have run Maintenance Technology 4.0 in the repair and maintenance of gensets. A non-probability sampling method, namely convenience sampling, was used to get the sample used. The number of respondents was 102 technicians. The analytical tool used is SEM-PLS 4.0. The results prove that the fabrication and operational failure factors do not affect the equipment's reliability. In contrast, the fabrication failure factor does not affect Maintenance Technology 4.0 but differs from the operational failure factor, which influences Maintenance Technology 4.0. Next, Maintenance Technology 4.0 affects equipment reliability. Meanwhile, Maintenance Technology 4.0 mediates the effect of operational failure factors on equipment reliability. In addition, Maintenance Technology 4.0 does not mediate the impact of fabrication failure factors on equipment reliability.

Keywords: Fabrication Failure Factors, Operational Failure Factors, Maintenance Technology 4.0, Equipment Reliability

INTRODUCTION

Electrical energy is a primary need in modern human life in Indonesia. Electricity demand continues to increase along with economic growth, population and industrial development. Indonesia's per capita electricity consumption will reach 1,109 kWh in 2021. However, electricity infrastructure is still uneven throughout Indonesia, causing electricity consumption growth outside Java to be faster than electricity infrastructure.

PT. PLN, as the country's only electricity provider, is unable to meet the increasing electricity demand, which has caused many private parties to enter the market by selling generators. Product reliability and performance are critical to customer satisfaction and the influence of brand reputation on customer perception.

The generator industry drives design by power capability, efficiency, reliability and service life. Proper maintenance arrangements are necessary to maintain high reliability to overcome inevitable breakdowns. In the Industry 4.0 environment, new technologies such as CPS, IoT, and IoS are used to develop more innovative maintenance methods.

The application of Maintenance Technology 4.0 can make intelligent decisions in generator maintenance, thereby increasing customer satisfaction and minimizing damage to equipment.

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METHODS

Literature Review. The following are several theoretical frameworks that form the basis of this research, namely:

Generator. A generator combines a generator and engine assembled in one package and uses fuel such as diesel, biogas, landfill gas, natural gas, or other fuels. Generators convert mechanical energy into electrical energy and are very important in providing electricity for various activities. Generator maintenance management is critical to ensure proper operation and prevent major failures (Turindah & Sofianti, 2018).

Maintenance Management. The definition of maintenance, according to European Standard EN 13306:2017, is a combination of technical, administrative and managerial actions aimed at maintaining or restoring an item so that it continues to function correctly. Maintenance planning involves developing regularly scheduled work programs to ensure satisfactory equipment operation and prevent significant problems. Maintenance plays a vital role in the success of manufacturing companies because it impacts productivity and quality. Maintenance management requires full attention because it involves various functions and business activities of the organization (Dhillon, 2002).

Maintenance Technology 4.0. Maintenance has evolved from reactive to predictive and prescriptive in recent years, known as Maintenance 4.0. Maintenance Technology 4.0 leverages the Internet of Things, cloud computing, and new technologies such as Augmented Reality and Virtual Reality to improve equipment reliability and availability. Applying this advanced technology in maintenance helps predict failures, diagnose problems, and trigger maintenance actions (Jasiulewicz, 2020).

Diesel Generator Failure. The generator set mainly consists of an engine, an AC synchronous generator and a control box. Internal and external causes, such as the nature of the materials and oil, the structural characteristics of engine parts, and poor maintenance, can lead to generator failure. Understanding the causes of generator failure can help plan more effective maintenance and prevent more severe failures.

Tool Reliability. Reliability is a product attribute that determines how well a product can meet customer expectations over time. The tool reliability evaluation process involves data collection, analysis, condition monitoring, reliability modeling, risk evaluation, corrective action, continuous monitoring, and results reporting. Following these business processes can help organizations improve the reliability of their tools and operational performance.

Hypothesis.

H1 : Manufacturing Damage Factors have a significant effect on Equipment Reliability.
H2 : Operational Damage Factors have a significant effect on Equipment Reliability.
H3 : Manufacturing Damage Factors have a significant influence on Maintenance Technology 4.0.
H4 : Operational Damage Factors have a significant effect on Maintenance Technology 4.0.
Maintenance Technology 4.0 has a significant effect on equipment reliability.
H5 : Maintenance Technology 4.0 mediates Manufacturing Damage Factors on Equipment
H6 : Reliability.
H7 : Maintenance Technology 4.0 mediates Operational Damage Factors on Equipment Reliability.

METHOD

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The positivistic paradigm is used in this research with a quantitative approach to measure the constructs that form the conceptual model. This research examines manufacturing and operational damage factors, the application of Maintenance Technology 4.0, and equipment reliability in PT generator products. XYZ. This research is explanatory and causal associative, with a sample of generator technicians from PT. XYZ, which has been running Maintenance Technology 4.0. The minimum sample required is 55 respondents, but 102 valid respondents were obtained.

The framework for this research includes Manufacturing Damage Factors, Operational Damage Factors, Maintenance Technology 4.0, and Equipment Reliability. The research hypothesis involves these factors and examines the relationships between them. The data analysis method uses partial least squares structural equation modeling (PLS-SEM) with the help of the SmartPLS 4.0 program. Descriptive statistical analysis is used to identify respondent characteristics, while inferential analysis is used to test research hypotheses.

Hypothesis testing was carried out using Bootstrapping resampling and mediation analysis. Validity and reliability tests were conducted by checking Pearson correlation and Cronbach Alpha. The results of data analysis are used to interpret and draw conclusions regarding the influence of factors on the reliability of generator equipment. This method can help strengthen or reject previously existing theories or hypotheses.

RESULT AND DISCUSSION

One hundred two questionnaires are suitable and complete to be processed and obtained online via Google Forms and in person. Of the 150 questionnaires distributed, 102 respondents responded. The questionnaire return rate was 68%. After checking using Google Forms, all data entered is suitable for processing. The respondent is a technician from PT. XYZ is a distributor of generator engines in Indonesia with experience in generator engine repairs. Respondent characteristics included gender, age, education level, work area, length of time as a technician, and number of repairs in the last year.

PLS Output Analysis Results. The results of the Partial Least Square (PLS) analysis are a Structural Equation Modeling (SEM) technique that aims to maximize the explanation of the variance of endogenous variables with two main parts, namely the measurement model or outer model and the structural model or inner model. The measurement model is used to test the validity and reliability of the construct using convergent validity, discriminant validity and composite reliability.

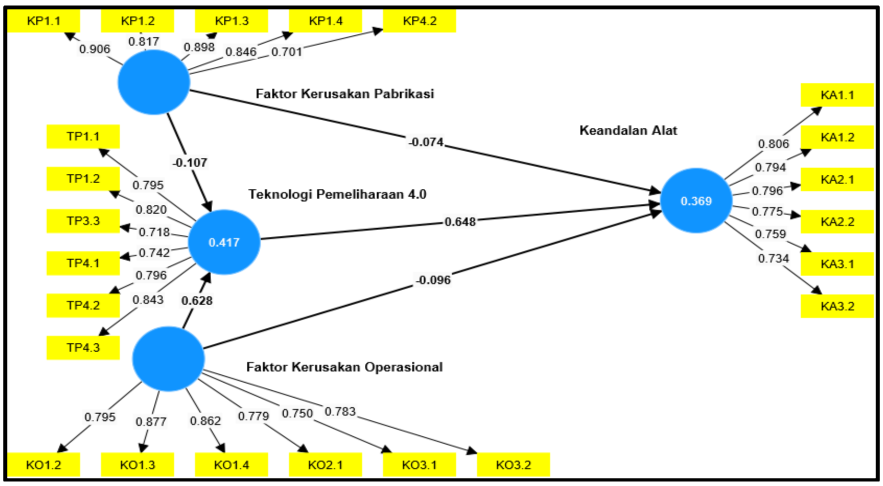

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Figure 1. PLS Structural Model Diagram

Convergent validity testing was carried out by looking at the outer loading of the measurement model using the rules established by Chin (1995) and Hair et al. (2014). The results show that the PLS model indicators have met the convergent validity requirements. The measurement model in this research uses reflexive indicators for the variables manufacturing damage factors, operational damage factors, Maintenance Technology 4.0, and tool reliability.

The analysis results show that all latent variables have an outer loading value greater than 0.7 and a t-count value more significant than the t-table, so the convergent validity test is fulfilled. In addition, the Average Variance Extracted (AVE) value is also greater than 0.5, strengthening this conclusion. Next, discriminant validity testing used the Fornell-Larcker criteria and cross-loading. The results show that all latent variables have a square root AVE value more significant than the correlation value between the other variables, indicating the existence of good discriminant validity.

Composite reliability testing was also carried out to measure the reliability of the indicators of the research variables. The results show that all variables have a composite reliability value greater than 0.7 and an ideal Cronbach's Alpha value, indicating good reliability. In the structural model, testing is done by looking at the R-Square (R2) value, which shows the model's strength. The R2 value for the endogenous variable, namely Maintenance Technology 4.0 with a value of 0.379 and tool reliability with 0.380, indicates moderate model strength because it falls in the range of 0.35 to 0.67 (Chin, 1998).

The results of evaluating endogenous variables with f2 effect size concluded that the variables Maintenance Technology 4.0 and tool reliability had a significant influence. Q2 value from structural test results using SEM PLS model validation with predictive relevance values. From the data, the Maintenance Technology 4.0 variable received a score of 0.379 (Moderate) and tool reliability with a score of 0.380 (Moderate). These results demonstrate strong predictive validity. The structural model is fit and relevant with a Q2 value above 0.35.

Thus, the results of the Partial Least Square (PLS) analysis show that the model formed has met the requirements for validity, reliability and significance in testing the research hypothesis regarding the relationship between the variables of manufacturing damage factors, operational damage factors, Maintenance Technology 4.0 and equipment reliability.

Hypothesis Test. Next, hypothesis testing was carried out using SEM-PLS and Bootstrapping. The results show a significant influence between operational damage factors and Maintenance Technology 4.0 on equipment reliability. Meanwhile, manufacturing damage factors have little influence on tool reliability. The mediation test was carried out using the Sobel Test, and the results showed that the indirect influence of operational damage factors and Maintenance Technology 4.0 on equipment reliability was significant.

Table 1. Results of Testing Direct and Indirect Effects

Direct Connection				**Indirect Relationships**			
Variable Relationships	Path Coefficient	t-statistic	Information	Variable Relationships	Path Coefficient	*t-statistic*	Note
Manufacturing Damage Factors → Tool Reliability (H1)	0,634	0,476	Not significant	Manufacturing Damage Factors → **Maintenance Technology 4.0**→ Tool	-0,069	0,995	Not significant

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Operational Damage Factors → Tool Reliability (H2)	0,407	0,830	Not significant
Manufacturing Damage Factors → Maintenance Technology 4.0 (H3)	-0,107	1,034	Not significant
Operational Damage Factors → Maintenance Technology 4.0 (H4)	0,628	6,851	Significant
Maintenance Technology 4.0 → Tool Reliability (H5)	0,648	5,127	Significant
Reliability (H6)			
Operational Damage Factors → **Maintenance Technology 4.0→** Tool Reliability (H7)	0,407	3,940	Significant

Based on the research results in Table 1, H1 is rejected or not accepted, where the reliability of a generator is not directly influenced by initial damage originating from manufacturing. This finding does not follow research conducted by Scheu et al. (2019). Furthermore, H2 is rejected or not accepted where the reliability of a generator is not directly influenced by factors that cause damage originating from operational activities. This finding is not in line with Dinwoodie et al. (2014). For H3, it was also rejected or not accepted where the manufacturing damage factor had no direct effect on the application of Maintenance Technology 4.0 in the field. This finding does not align with the results of research conducted by Al-Najjar et al. (2018) and Eyers and Potter (2015).

Furthermore, H4 is accepted where operational damage factors directly influence the implementation activities of Maintenance Technology 4.0. This finding aligns with Almobarek et al. (2022) and Jasiulewicz et al. (2020). Then, H5 is accepted or not rejected, where equipment reliability in the field is significantly influenced directly by the application of Maintenance Technology 4.0, which aligns with research conducted (Jasiulewics et al., 2020).

Table 2. Mediation Test Results with Sobel Test

Exogenous Variables	Mediation Variables	Endogenous Variables	A	B	SE_a	SE_b	p-value	Z	Note
Manufacturing Damage Factors	Maintenance Technology 4.0	Tool Reliability	-0,107	0,648	0,103	0,126	0,320	-0,102	Not significant
Operational Damage Factors	Maintenance	Tool Reliability	0,628	0,648	0,092	0,126	0,000	4,107	Significant

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	Technology 4.0

Based on the calculation results using the Sobel Test as listed in Table 2 above, H6 is rejected or accepted. This shows that manufacturing damage factors cannot be increased in their influence on the reliability of a tool even through the implementation of Maintenance Technology 4.0. However, for H7, it is either accepted or not rejected. This means that the influence of operational damage factors on the reliability of a tool can be increased through the application of Maintenance Technology 4.0.

CONCLUSION

Based on previous research, the following conclusions were obtained: damage factors from manufacturing and operations do not directly affect equipment reliability, and damage from operations affects the application of Maintenance Technology 4.0. Furthermore, Maintenance Technology 4.0 mediates the contribution of operational damage to tool reliability. However, Maintenance Technology 4.0 does not affect tool reliability due to manufacturing defects. This research also develops a new model where equipment reliability is determined not by manufacturing or operational damage but by applying Maintenance Technology 4.0 as mediation. This model integrates manufacturing damage, operational damage, Maintenance Technology 4.0, and tool reliability factors as one unit. This is important in increasing the reliability of tools with the latest technology according to the Industry 4.0 era.

Suggestion. The suggestions from this research are for PT. XYZ pays attention to the application of Maintenance Technology 4.0 in equipment reliability issues. The focus of repairs is directed at operating the generator according to the Instruction Manual, maintaining proper air conditions, loading the generator according to specifications, doing routine maintenance, and regulating room temperature. This research could be improved by examining other variables related to tool reliability. Interviewing with a tool reliability expert for more complete information is recommended. Further research could use a longitudinal data approach for more accurate results.

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