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HUMAN RELIABILITY ANALYSIS OF PACKAGING PRODUCTION OPERATORS WITH HIERARCHICAL TASK ANALYSIS (HTA) AND FUZZY HEART METHODS

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Abstract Machine operator experienced has a significant number of production defects and frequent failures to meet production targets. These issues are largely attributed to the high level of operator involvement in the production process, increasing the likelihood of human error. To address this, a Human Reliability Analysis (HRA) was conducted to identify factors contributing to human error and the associated risks of production defects. The analysis employed the Hierarchical Task Analysis (HTA) method to break down each task. Subsequently, Human Error Probability (HEP) and the Human Error Assessment and Reduction Technique (HEART) were used to evaluate the likelihood of human error and overall human reliability. In the HEART method, the Assessed Proportion of Effect (APOE) value was determined through expert judgment. To mitigate the subjectivity in APOE determination, a modification using Fuzzy Linguistic Expression was applied.
Keywords: **Human Reliability Analysis, Human Error Assessment and Reduction Technique, Fuzzy Linguistic.Technique, Fuzzy Linguistic.**

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1. Introduction

The problems that occur in the production process at PT CGK Karawang are the large number of production defects and often not achieving production targets. According to the production manager, this problem occurred due to human error by the machine operator, resulting in a mismatch in production results with the targets given by the company. To find out the causal factors that occur, the method used in this research is Hierarchical Task Analysis (HTA) and then an assessment of the opportunity for errors to occur in operators is carried out using the Human Error Assessment and Reduction Technique (HEART) method (Khilbran, M, & Sakti, W. I.,2019). To reduce the level of subjectivity with the HEART method, a modification was made to determine the APOE value using Fuzzy Lingustic Expressions Herawati, et al.,2023). From the Fuzzy HEART method used, the Human Error Probability (HEP) value is obtained as input for analyzing the causes of human error in operations that have the highest HEP value using the Root Cause Analysis (RCA) method Casamirra, M., et al.2009).

Fuzzy HEART improves upon traditional HEART in human error assessment by addressing the subjectivity inherent in the traditional method. Traditional HEART relies on expert judgment to assign the Assessed Proportion of Error (APOE) values, which can introduce bias and inconsistencies in evaluation. By incorporating Fuzzy Linguistic Expressions, Fuzzy HEART refines the APOE determination process, making it more structured and reducing variability in expert opinions (Castiglia & Giardina, 2011).. In the case of PT CGK Karawang, Fuzzy HEART helps in achieving a more precise Human Error Probability (HEP) value, which is then used to analyze the most critical human errors using Root Cause Analysis (RCA) ada (Siregar et al., 2019) . This improvement enhances decision-making in identifying and mitigating factors leading to production defects, ultimately improving operational efficiency and reducing human error in machine operations.

the following are the types of machines in the Carton Box Department, production targets, production results, and production defects produced in the packaging production process at PT CGK in 2023

Table.1 Product Result and Defect

No	Mesin	Dept.	Target	Hasil P	Cacat	% cacat
1.	Flexo Emba 2 Lines 2 Color	Karton Box	10.600 MT	10,946 MT	573 MT	5.23%
2.	Flexo Slotter WARD 3 lines 3 Color		10.600 MT	11,341 MT	616 MT	5.43%
3.	Flexo Diecutter WARD 2 Lines 4 Color		9.800 MT	9,667 MT	746 MT	7.72%

Several types of production defects are caused by human error factors, including lack of precision in the location of the plate on the roll plate in the printing machine which results in the print results not matching the expected pattern, lack of press level in the die cutting section which results in the cardboard not being cut perfectly.

Below are detailed data on the types and the number of production defects produced by the WARD 2 Lines 4 Color Flexo Diecutter machine or what will be called the B6 Flexo machine in 2023.

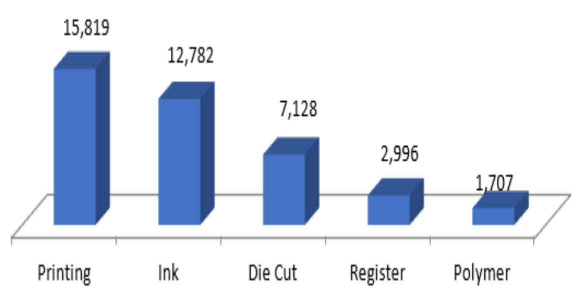

Figure 1. Chart of Types and Number of Production Defects

2. Methods

The method in this research starts from the literature study, data collection, data analysis and discussion, and conclusions. Literature studies are conducted by searching for previous studies on human reliability and its methods. The data collection method was used to gather data about operator's activity by Hierarchical Task Analysis (HTA). This stage is the basis for calculating the next stage, namely identifying possible errors, calculating EPC, APOE, AE, HEP, and HR.

3. Result and discussion

The production process at PT CGK Karawang faces challenges due to high defect rates and frequent failures in meeting production targets, primarily caused by human errors in machine operations. To address this issue, this study integrates Hierarchical Task Analysis (HTA), Fuzzy HEART, and Root Cause Analysis (RCA) to systematically identify and assess human error factors. Traditional Human Error Assessment and Reduction Technique (HEART) methods often rely on expert judgment, which can introduce subjectivity. To enhance accuracy, this research modifies HEART by incorporating Fuzzy Linguistic Expressions, ensuring a more structured and consistent evaluation of human error probabilities (Achola,T.,etal.2019). By refining the Assessed Proportion of Error (APOE) calculation, Fuzzy HEART minimizes bias and provides a more precise Human Error Probability (HEP) value, which serves as the basis for identifying critical human error causes through RCA (Ngatilah,Y., et al 2019)..

This study's novelty lies in its integration of multiple methodologies to enhance human reliability analysis in an industrial production setting. Unlike conventional approaches that use qualitative RCA, this research quantifies HEP values, making the identification of root causes more data-driven. Applying Fuzzy HEART in a real-world manufacturing environment contributes to more accurate error assessments, leading to targeted improvements in operator training and production processes (Boroun,R..e et al 2022)(Pratama,R.A. 2017). The results provide valuable insights into reducing production defects and improving overall operational efficiency. By addressing the limitations of traditional HEART through fuzzy logic, this study offers a more reliable framework for human error assessment, which can be adapted across various industrial applications. For find this we do some procedure bellow

3.1 Hierarchical Task Analysis (HTA)

The aim of the HTA method is to describe each activity carried out by the production operator for analysis on each task. Data on assessing the intensity of error occurrence was obtained based on the results of interviews with 3 experts, namely the shift head.

3.2 Identify Possible Errors

Identification of possible errors can be done by analyzing each of the simplest activities carried out by operators in the production process by observing directly in the field and considering the results of direct interviews with production operators, shift heads and production managers.

3.3 Task classification according to Generic Task

This task classification stage was carried out based on the results of direct observations by researchers as well as the results of direct interviews with shift heads and production managers. Apart from interviews, at the task classification stage, direct discussions were held with experts who then classified each activity that had possible errors.

3.4 Identify Error Producing Conditions (EPC)

The Error Producing Conditions (EPC) identification stage is an advanced stage of task classification which is in accordance with the generic tasks in the Fuzzy HEART method. At this stage, identification and classification are then carried out according to conditions in the field using a predetermined EPC table. From each classification using the EPC table, the EPC value that is attached to each type of possible cause of error that occurs will be obtained

3.5 Expert Assessment for APOE

The set of linguistic variables in this calculation is divided into five sets, including Very Low (VL), Low (L), Medium (M), High (H), Very High (VH). Each set of linguistic variables has 3 parameters (li, mi, ui) which are the regional boundaries of each set of fuzzy numbers.

3.6 Fuzzy Number Expert Assessment for APOE

The experts' assessments in the form of linguistic variables are then converted into a set of fuzzy numbers. li, mi, ui are the results of converting linguistic variables into fuzzy numbers.

3.7 Arithmetic Mean of Expert Ratings for APOE

After converting the linguistic variable values into fuzzy numbers, the fuzzy number values obtained from each task are calculated on average using the arithmetic average calculation according to the previous calculation.

3.8 Defuzzification

The defuzzification process is to obtain the crisp APOE number value, which is then used in the AE calculation. In carrying out the defuzzification process to get the crisp APOE value, use the COG triangle method for each task which can be seen in the APOE value column. An example of this defuzzification calculation can be seen as the arithmetic average of the experts' assessments in task 1.1.1 with the following calculation results:

$$\text{APOE} = \frac{(u_i - l_i) + (m_i - l_i)}{3} + l_i \quad (1)$$

$$= \frac{(0.367 - 0.033) + (0.200 - 0.033)}{3} + 0.033$$

$$= 0.2$$

3.9 Calculation of Assessed Effect (AE)

For each task there is an EPC value that is used in AE calculations. As an example of AE calculations, you can see that the AE numbers in task 1.1.1 are obtained from the following calculation results:

$$AE = [(value\ of\ EPC - 1)APOE + 1] \quad (2)$$

$$= [(1.2 - 1)x0.200 + 1)] = 1.04$$

3.10 Calculation of Human Error Probability (HEP) and Human Reliability (HR)

The HEP calculation is carried out based on the generic task value and the AE value obtained for each task. For example, the HEP calculation can be seen in task 1.1.1 which has a HEP value of 0.096 which is obtained from the following calculation results:

$$HEP_{1.1.1} = Nominal\ Generic\ Task\ x\ AE \quad (3)$$

$$= 0.02x1.040 = 0.021$$

Meanwhile, HR calculations are carried out using the formula 1 - total failure (HEP).

Table 2. HEP and HR calculation results

No Task	Activity	Possible Error	Generic Task Nominal	AE	HEP	HR
1.1.1	Checking the plate according to the design reference	Plate usage error	0.02	1.040	0.021	0.979
1.1.2	Checking the suitability condition of the plate	There is a defect in the plate and the condition of the plate is no longer flexible	0.02	1.030	0.021	0.979
1.1.4	Plate Mounting Process	The position of the mounting plate is not suitable	0.16	1.220	0.195	0.805

1.2.2	Checking the condition of the ink roller (anylox)	There is a defect in the ink roller (anylox)	0.02	1.300	0.026	0.974
1.2.3	Cleaning the ink roller from residual ink	The remaining ink is still stuck to the ink roll	0.02	2.133	0.043	0.957
1.4.2	Checking the condition of the cardboard sheet	Cardboard sheet bends beyond tolerance limits	0.02	1.300	0.026	0.974
1.5.1	Installation of the plate must match the color type of the ink tank	*The plate does not match the color of the ink tank*	0.09	1.030	0.093	0.907
1.5.2	Setting the plate installation on the roller	Installation of the plate is less precise on the roll	0.09	2.400	0.216	0.784
1.5.3	The measurement of the plate position must match the position of the other color plate and the die cut pattern	Installation of the plate is less precise on the roll	0.09	2.400	0.216	0.784
1.8.1	Mixing ink according to the reference color	The composition of the ink mixture is not right	0.16	2.700	0.432	0.568
1.8.3	Checking that the ink liquid adheres evenly to the ink roller	The ink roller is not cleaned properly	0.02	1.340	0.027	0.973
1.10	Setting the size and position of the pattern cutting (die cut)	Wrong setting of die cut knife position	0.09	2.400	0.216	0.784
1.11	Setting the register position	Wrong position setting between plates	0.09	2.400	0.216	0.784
2.1.1	Checking the print results according to the design reference	Not being thorough in the process of checking the design with references	0.02	1.113	0.022	0.978
2.1.2	Checking the print results for parallel register color lines	Not careful in the process of setting the precision plate on the roll	0.02	2.400	0.048	0.952
2.1.3	Check the cut size according to the die cut line pattern	The installation position of the knife and plate does not match	0.02	2.400	0.048	0.952
2.1.4	Checking the quality of print results	Print results are not checked regularly	0.02	1.113	0.022	0.978
2.1.5	Set the cutting position according to the die cut line pattern	Wrong setting of die cut knife position	0.09	2.133	0.192	0.808
2.1.6	Setting the press roll level	The press roll settings are not quite right	0.09	1.400	0.126	0.874
2.2.1	Set the composition of ink, supporting chemicals and water according to the required dosage	The composition of the ink mixture is not right	0.16	2.600	0.416	0.584
2.2.2	Sampling print results according to the specified color brightness level every 30 minutes	Routine sampling and checking is not carried out	0.02	1.040	0.021	0.979

2.2.3	Make ink adjustments if the color does not match the reference	Color adjustments are not done often	0.16	1.073	0.172	0.828
2.4.1	Checking the quality and cleanliness of the print results	Print results are not checked regularly	0.02	1.400	0.028	0.972
2.4.2	Checking plate cleanliness	Plates are not cleaned regularly	0.02	1.400	0.028	0.972
2.4.3	Clean the plate from ink that sticks to it every 120 minutes	Plates are not cleaned regularly	0.09	1.040	0.094	0.906
3.2	Sorting and recording production results	The sorting process is less than optimal	0.02	1.020	0.020	0.980

4. Conclusion

Future research in the packaging industry should focus on the integration of advanced automation technologies to enhance operator reliability and mitigate human error in critical production processes. Do explore the development of an intelligent ink-mixing framework incorporating real-time spectrophotometric sensors for precise color matching, AI-driven process optimization algorithms, and closed-loop control systems for continuous calibration. Reducing human intervention and improving overall process stability.

The integration of automation in the packaging production process necessitates a structured transition from conventional manual operations to cyber-physical production systems (CPPS).Involve the deployment of collaborative robotics (cobots) for ink handling, adaptive control mechanisms for real-time process adjustments, and augmented reality (AR)-assisted operator training to ensure seamless adaptation. By aligning with advanced manufacturing trends, such as digital twins and smart factory initiatives, the integration of automation in the packaging industry will drive efficiency, minimize operational risks, and enhance production quality.

This study has several limitations, including the reliance on expert judgment in error assessment, which may introduce subjectivity despite the use of Fuzzy Linguistic Expressions. The effectiveness of Fuzzy HEART also depends on the selection of linguistic variables, which may not be universally applicable. Additionally, the study focuses solely on human errors without considering machine failures or environmental factors that could impact production. Since the research is limited to PT CGK Karawang, its findings may not be fully generalizable to other industries. Future research should incorporate machine learning for real-time error prediction and validate the approach in diverse industrial settings.

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