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Human Reliability Analysis on Fresh Fruit Bunches Sorting Workers

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Abstract. *Demand for Crude Palm Oil (CPO) at PT. Wijaya Borneo Tiganna for this year has increased. However, the increase in production was not in line with human error of 74% in the Fresh Fruit Bunches (FFB) Sorting Department from the 80% minimum percentage desired by the company. The purpose of this study was to analyze the reliability value of sorting workers. The method used is the Human Reliability Assessment Method seen from related tasks and context related to identify Human Error Probability (HEP) with a fault tree to provide recommendations for reducing human error. There are 3 types of rework in the TBS Sorting Section. The HEP using the HEART method is 1.1103148 while the CREAM method is 0.10608. The reliability of workers in carrying out tasks can still be improved with skills and accuracy in the sorting and grading of FFB.*

Keywords: *human reliability assessment; fault tree; task related; context related.*

I. INTRODUCTION

The largest producer of palm oil in the world and its industry has become a mainstay in the economy because palm oil is one of the sources of foreign exchange earnings from exports from the agricultural sector is Indonesia. The results of oil palm plantations contribute greatly to regional development as an important source of poverty alleviation through cultivation and downstream processing (Purba, 2019).

There are several stages in the palm oil production process. Sorting process or grading is an activity carried out to determine the quality and sort of Fresh Fruit Bunches (FFB) that enter the processing plant to be processed into CPO (Ishak et al., 2019). At this stage the fruit that comes from the garden, be it nucleus, plasma or community gardens, is inspected. The purpose of the inspection in the FFB sorting process is to determine the quality of FFB received by the factory. The sorting process shown in Figure 1.

Figure 1. Sorting Process

In addition, reports to the gardener (escape) or the quality of FFB received, as a reference or basis for calculating payments that must be borne by the factory to third parties (fruit suppliers) and as a parameter in analyzing the quality of production by the factory (Alfatni et al., 2020). Two methods in the Sorting Process are random checks or total checks (Alfatni et al., 2020). Random inspection is inspection with a minimum of 5% of the number of trucks coming from a plantation (afdeling) (Yousefi D.B. et al., 2021). The process is carried out by unloading FFB from the truck on the loading ramp floor. It is in this inspection section that human errors often occur

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because workers must distinguish between several acceptable FFB qualities. The data for the productivity of sorting workers in 2021 shown in Figure 2.

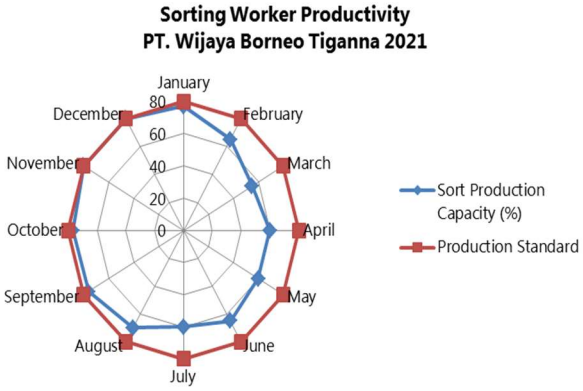

Figure 2. Productivity of Sorting Workers PT. Wijaya Borneo Tiganna 2021

Productivity is affected by worker performance (Crowley, 2020). Human error has the effect of reducing production output, especially the sorting section. This affects the reliability of workers in doing work (Rafael et al., 2019). The study was conducted to analyze the level of human reliability.

The Human Error Assessment and Reduction Technique (HEART) method is a method to analyze operator reliability by reducing worker errors when working at the Palm Oil Boiling Station. The results obtained from this study revealed that the highest value of Human Error Probalility (HEP) was seen when the operator performed the task of setting the boiling time around 0.5324 (Hasibuan et al., n.d.). Application of Hierarchical Task Analysis (HTA) and HEART Method to identify major errors in mitigation actions taken after detection of fire on board passenger ships (Navas et al., 2022). Hasan, A. et.al. using the HEART Method to analyze human errors in nuclear power. The results of their research will be applied in qualifying the frequency of the end state of the sequence of events in the probabilistic safety assessment (PSA) (Hassan et al., 2020). Measurement of operator reliability using HEART has also been carried out by Y S Rejeki et.al. in a company that manufactures auto parts and machinery. Product defects about 1.2% are caused by human error (Rejeki et al., 2020).

Human reliability research using the Cognitive Reliability And Error Analysis (CREAM) method was conducted by Zhou Q et.al. The research analyzes human reliability in the tanker shipping industry. HEP is obtained from the control mode membership and the result of Bayesian network reasoning (Zhou et al., 2018). The application of the CREAM method is expanded with fuzzy to measure the reliability of operators in operating high-speed trains (Chen et al., 2021). Human Reliability Assessment (HRA) is used to improve the safety and reliability of complex socio-technical systems. The CREAM method is part of HRA that can qualify and measure performance so that it can provide information for future HRA areas (Hou et al., 2021). Human error assessment in an emergency using Fuzzy Bayesian CREAM. The result obtained is that the method used can be applied to overcome the traditional method, with the condition that it is an iterative method for assessing human error and managing human error in an emergency (Rasmussen & Laumann, 2018).

Based on the problems above, this study raises the application of the Human Reliability Method (HRA) in identifying task and cognitive factors that affect worker productivity. The purpose of this study is to analyze the reliability value of sorting workers so that it can be used as a basis for identifying the increase in work productivity of sorting workers at PT. WIjaya Borneo Tiganna.

II. Research Method

Research Object

The research was conducted at PT. Wijaya Borneo Tiganna which is a palm oil company in Batang Kulur Village, Kelumpang Hilir District, Kotabaru Regency, South Kalimantan. The population of this research are workers in the Workshop Department of PT. Wijaya Borneo Tiganna. The sample of this research is 18 sorting workers. The tools used in this study include

questionnaire sheets, HEART tables, CREAM tables, stopwatches.

Data collection is a recapitulation obtained based on the main research results. The first research obtained primary and secondary data, working conditions in the sorting section of PT. Wijaya Borneo Tiganna, identification of errors that have occurred in the sorting section due to human error and identification of sub-tasks to be investigated.

In the sorting section there are 18 workers who do their respective tasks. The research tool is the SOP task. In every job carried out by sorting workers, the tasks carried out are not only basic tasks but there are supporting tasks in working on the main task. The sorting worker task is divided into several tasks that contribute errors to the sorting worker. For this reason, it is necessary to break down before analyzing the HRA method.

Research Methods

HRA is a qualitative and quantitative method to measure the human contribution to risk. There are 3 generations in the HRA Method. The first generation mostly has a goal to help calculate risk and quantify the frequency of occurrence of human error. The second generation is widely discussed about the context and error of commission in measuring human error. Many new methods have been developed based on previous methods in the first generation, such as the HEART method which developed into the HRA method in the third generation (Hou et al., 2021). The HRA method that developed from the first generation to the third generation and its division

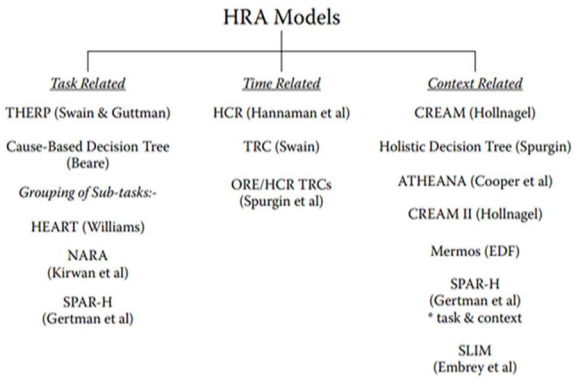

Figure 3. HRA Method based on its analysis

based on task analysis, time analysis and competitive analysis can be seen in .

The next stage is the analysis of task i. At this stage, there are instructions for analyzing tasks based on the type and number of tasks for the sorting workers that contribute to errors. So one by one it will be analyzed using the HRA method and if there are other tasks it will be analyzed again from the beginning of the method.

Measuring the reliability of the Sorting Section workers with the HEART Method. HEART was first introduced by Williams in 1985. This method is a method designed as a fast and simple HRA method in quantifying the risk of human error. This method can generally be used in situations or industries where human reliability is important. There are 9 GTTs described in this method, each with HEP and 38 EPC which may have an impact on job reliability. Based on the EPC, the error effect is calculated through the proportion of the EPC. The calculation of the probability of human error is done by multiplying the human unreliability according to the generic task obtained with the EPC value (Navas et al., 2022).

Measuring the Reliability of Sorting Workers with the CREAM Method. In the division of tasks, if the workers in the sorting section perform tasks based on cognitive factors (context), namely decision factors based on considerations of company regulations, oil palm procedures and so on, the reliability measurement method used is the CREAM method. At this stage, detailed identification procedures (SOPs) related to errors that occur are associated with inappropriate cognitive functions.

Identify Human Error with Fault Tree. Tasks that have a high HEP value from each method are combined in a fault tree to determine the cause and effect relationship of the task. The research tool is a fault tree. Fault Tree Analysis (FTA) is a method to identify failure patterns. The definition of FTA is a top-down approach to analyzing failures, starting with a potential event or accident called a top event and determining how that event could have occurred. FTA is widely used as a technique to analyze the causal relationship in a risk or reliability measurement.

III. Results and Discussion

The Result of Calculation of Sorting Workers' Reliability with the HEART Method

The HEART method is an operator reliability method using several stages. In the division of tasks, if the sorting workers are able to perform tasks based on their abilities and routine skills, the reliability measurement method used is the HEART method. The research tools are operator task data and HEART table.

The steps that must be taken to determine the HEP using the HEART method can be described as follows: First, classifying the types of tasks/jobs in general. There are 8 (eight) different general task types Generic Task Type (GTT), from A to H, each with HEP (Bakhtiar et al., 2022). GTT is distinguished based on the characteristics or traits that describe the task being assessed as shown in Table 1. Second, determine the unreliability value of the task/job with the HEP value for each GTT task. Third, identify the conditions that give rise to errors (EPC). The EPC is required to be separate from what is covered by the GTT and should have a tangible nature. The HEART method contains 38 Error Producing Conditions (EPC) that may have an impact on job reliability (Kandemir & Celik, 2021).

Fourth, determine the proportion of errors. For each EPC identified in step 1, expert judgment provides an assessment of the overall unreliability affecting the task. Fifth, the determination of HEP can be calculated by estimating the unreliability assessment of an operator's task. First, determine

Table 1. Generic Task

Task Type	Jobs with high Rework Frequency	Task Type	General Job Description	Magnitude of the Proposed Human Unreliability Value
Task 1	Delays in the process of unloading FFB from transport vehicles	(D)	Fairly simple work, done quickly or requiring little attention	0,11
Task 2	Difficulty sorting unloaded FFB on the floor	(C)	Work/tasks are complex and require a high level of understanding and skills	0,18
Task 3	Error when loading raw or rotten FFB onto the vehicle	(E)	Routine, well-trained, low-skill work	0,031

Table 2. HEP Value HEART Method FFB Sorting Departement

Task Step	***Generic Task***	***Calculation***				**HEP**
		EPC	8	17	34	
		Nilai EPC	6	3	1.05	
1	D	*Proportion*	0.4	0.4	0.4	0.00352
		Assessed Effect	2.00	0.80	0.02	
		GTT	0.11	0.11	0.11	
		EPC	2	14	24	
		Nilai EPC	11	4	1.6	
2	C	*Proportion*	0.8	0.8	0.8	1.10592
		Assessed Effect	8.00	2.40	0.48	
		GTT	0.12	0.12	0.12	
		EPC	10	27	34	
		Nilai EPC	5.5	1.4	1.05	
3	H	*Proportion*	0.6	0.6	0.6	0.0008748
		Assessed Effect	2.70	0.24	0.03	
		GTT	0.045	0.045	0.045	

Table 3. Proposed Improvement of TBS Sorting Department

No	Conditions on the Line that Cause Rework	Rework Improvement Proposal
1	Delays in the process of unloading FFB from vehicles	It is better if the Loading Ramp is under the roof (not in an open area without a roof) so that when it is hot and heavy rains, activities to reduce FFB from vehicles can run well
2	Difficulty sorting unloaded FFB on the floor	create a sorting system to determine the quality of FFB by using a more objective quality analysis tool; make a FFB maturity research system because so far the assessment is still subjective
3	Error loading raw or rotten FFB onto trucks	It is recommended that the Loading Ramp position parallel to the height of the vehicle carrying raw or rotten FFB, so that workers do not experience Musculoskeletal complaints (MSDs) when they have to load raw or rotten FFB into the vehicle.

the task in its general form (generic task) on the problem. Second, determine the conditions that cause errors (EPC) associated with E (total HEART effect) for each EPC, then perform a proportion assessment (APOA) by indicating P for each error (EPC) that affects the operator's task. Table 2 shows the HEP value of the HEART Method at the FFB Sorting Department.

HEP value for each factor. The biggest factors need to be improved in order to reduce human errors so as to reduce the error rate. Figure 4 shows the HEP value of the FFB Sorting Process using the HEART Method. HEP value for each factor. The biggest factors need to be improved in order to reduce human errors so as to reduce the error rate.

The HEP value describes the potential rework that occurs in the FFB Sorting Process. The biggest rework potential in the FFB Sorting Process is Task 2, which is sorting FFB. The FFB Sorting process consists of separating FFB from impurities (twigs, sand and empty bunches) and grading based on the maturity level of FFB. The maturity level of FFB is based on the number of loose fruit from the FFB.

FFB is said to be ripe 1 if the number of loose fruit is 25 – 50% of the outer fruit and is said to be ripe 2 if the number of loose fruit is around 50 – 75% of the outer fruit. This means that FFB Sorting Workers must pay close attention to the amount of loose FFB in a certain amount of FFB. The task constraints above have a significant influence on the results of FFB sorting. Some of the recommendations for improvement given by the Production Manager can be found in Table 3. Results of Rework Analysis of FFB Sorting Process Using the FTA Method on the HEART Method. Failure of the task that causes rework in the FFB Sorting Process using FTA.

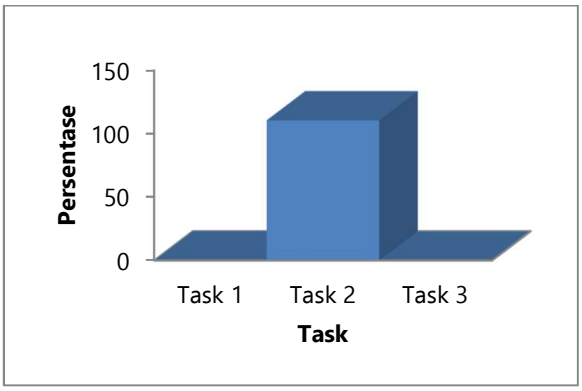

Figure 4. Comparison of HEP Values using Thes HEART Method in th FFB Sorting Process

FTA will describe the error pattern in doing the task due to human error and the probability of the failure occurring (Qiao et al., 2020). The potential for rework that occurs in the FFB Sorting Process can be seen in Figure 5.

The chance of rework in the FFB Sorting Process as measured by the HEART method is 1.1103148. In this FFB Sorting Process, there are 3 (three) types of tasks that indicate the type of rework that often occurs. The highest HEP value for the type of task that occurs in the FFB Sorting Process is Task 2. Task 2. The difficulty of sorting FFB that is unloaded on the floor is 1.10592.

Results of the Calculation of the Reliability of FFB Sorting Workers with the CREAM Method.

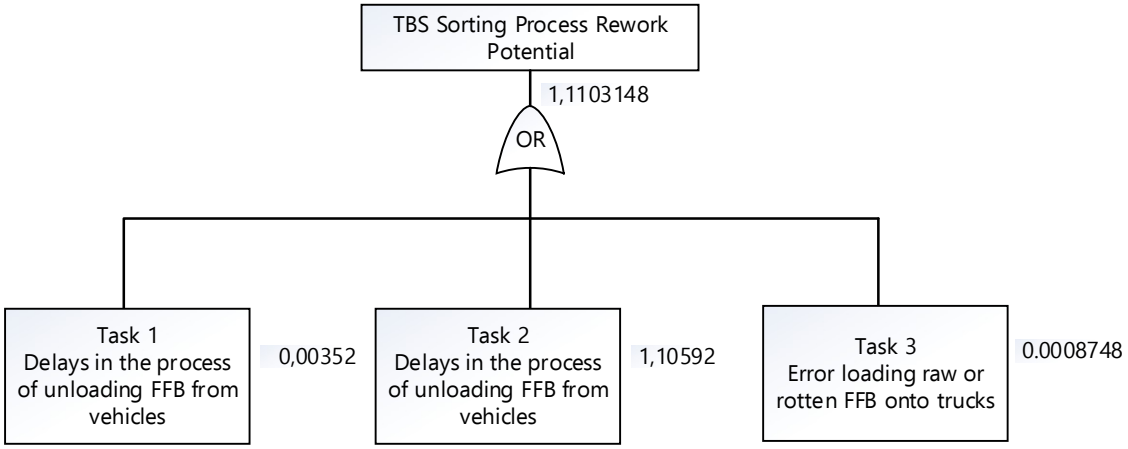

Figure 5. Potential Rework that Occur in the FFB Sorting Department

Table 4. FFB Sorting Worker Activity Procedure

Task	Type of Task	Sub Task
1	Lowering FFB from vehicles	1.1. Boarding the FFB transport vehicle from the Loading Ramp runway
		1.2. Lowering FFB to Loading Ramp with a sledgehammer tool
		1.3. Get off the FFB transport vehicle because the job is done
2	Sorting FFB	2.1. Separating FFB from impurities (twigs, sand and empty bunches)
		2.2. Giving a classification (grading) based on the maturity level of FFB
3	Loading raw or rotten FFB onto vehicles	3.1. Loading raw or rotten FFB onto a vehicle with a sledgehammer

Table 5. CFPs adjusted for Cognitive Functional Failure for the Sorting Department

Task	Type of Task	Sub Task	Error Mode	Nominal CFP	Weighting Factor	Adjusted CFP
1	Lowering FFB from vehicles	1.1.	E1. Action of wrong type	0.009	0.64	0.00576
		1.2.	I3. Delayed interpretation	0.1	0.25	0.025
		1.3.	E1. Action of wrong type	0.009	0.08	0.00072
2	Sorting FFB	2.1.	P1. Priority error	0.1	0.2	0.02
		2.2.	I2. Decesion error	0.1	0.5	0.05
3	Loading raw or rotten FFB onto vehicles	3.1.	E1. Action of wrong type	0.009	0.512	0.004608

The CREAM method is a reliability method using cognitive functions. The steps in this CREAM Method are as follows (Mahdi Rezaie et al., 2021).

First, identify the error activity as shown in **Error! Reference source not found.**. At this stage the identification of error activities that occur based on work procedures carried out by workers in the FFB Sorting section is carried out. The task that makes the most rework in the TBS Sorting section is investigated to find out what error activities occur.

Second, identification of cognitive activity. The identification of cognitive activities performed by operators on error activities is based on the Cognitive Activity Table. Third, identify possible types of cognitive function errors. At this stage the possible types of cognitive function errors are identified by the operator. Identification is based on the Simple Model of Cognition (SmoC) method. Fourth, identify the initial cognitive failure probability. Based on the inappropriate cognitive function, the initial Cognitive Function Failure Probability

(CFPo) value can be determined. Fifth, assessment of Cognitive Failure Probability (CFP). Sixth, the Human Error Probability (HEP) assessment as shown in Table 5 below this.

In this section, the optimization of reliability analysis is carried out by optimizing the CPC factors so that the resulting HEP value will be minimum or human reliability will be maximum. Optimization approach based on the Cocom method recommended by Hollnagel (1998) which correlates CPC assessment with control modes (Zhang et al., 2021)].

Based on the overall calculation of the CEP error value for each task, the HEP value can be determined. Overall, all types of errors have a series relationship because one error will cause other parts to be unable to carry out the next step. Therefore, the whole is in series with high correlation, the HEP value is expressed as follows:

MAX {Max (Task 1.1., Task 1.2., Task 1.3.), (Task 2.1., Task 2.2.), (Task 3.1)} = Max {Max (0,025, 0,05, 0,004608)} = 0,05.

The magnitude of the HEP value determines the reliability value of FFB sorting workers. This is because the two values influence each other. The HEP value for FFB sorting workers is 0.05, which means the magnitude of the error probability value made by FFB sorting workers is 5% of the resulting product. So it can be stated that the level of reliability of sorting workers is 95%.

From the analysis of the reliability value and cognitive function based on the Control Mode Table, it can be concluded that the FFB Sorting Worker the HEP value for 0.05 is in the range of $0.01 < p < 0.5$, namely in the Opportunistic Control Mode. Opportunistic Control Mode is a control mode where the choice of action is inefficient, therefore the probability of success is limited. The existing anticipatory planning is not good, this may be due to the limited time available or because the context is not yet understood. Other possibilities that may affect are poor competence, changing conditions and poor working conditions.

HEP is the probability of errors made by humans in a certain period of time. The comparison of the FFB Sorting Workers' HEP values for each task using the CREAM Method is shown in Figure 6.

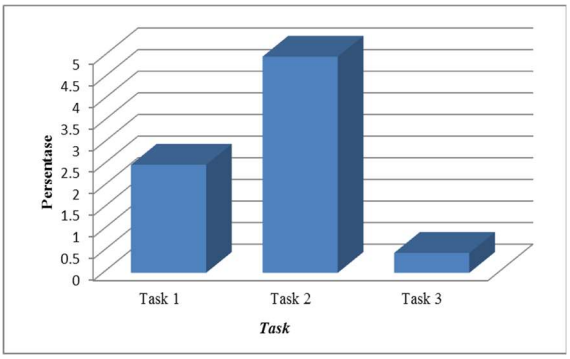

Figure 6. Sort Departement's HEP value using the CREAM Method

The task that has the greatest potential for failure is Task 2. Task 2 sorts FFB. The production process carried out by workers is the ability to provide FFB classification based on the level of maturity, whether full ripe fruit, half ripe fruit and unripe fruit. The error factor that often occurs is the process of sorting FFB in large quantities with unfavorable environmental conditions that will affect workers in sorting FFB according to the criteria determined by the company. Time and accuracy of FFB selection is very necessary.

The results of the Rework Analysis of the FFB Sorting Process Using the FTA Method on the CREAM Method can be seen in Figure 7. The chance of rework in the FFB Sorting Process as measured by using the CREAM Method is 0.10608. In this process there are 3 (three) types of tasks that indicate the type of rework that often occurs. The highest HEP value for the type of task that occurs in the FFB Sorting Process is Task 2. Sorting FFB at 0.07.

Comparison of Measurement Results Using the HEART and CREAM Metode Methods

Overall the results of measurements carried out using the HEART and CREAM methods have significant differences.

The following is a graph that illustrates the measurement results using the measurement results of all tasks using the HEART and CREAM Methods at the FFB Sorting Department. Figure 8 shows a graph of the measurement results of all tasks using both methods in the FFB Sorting

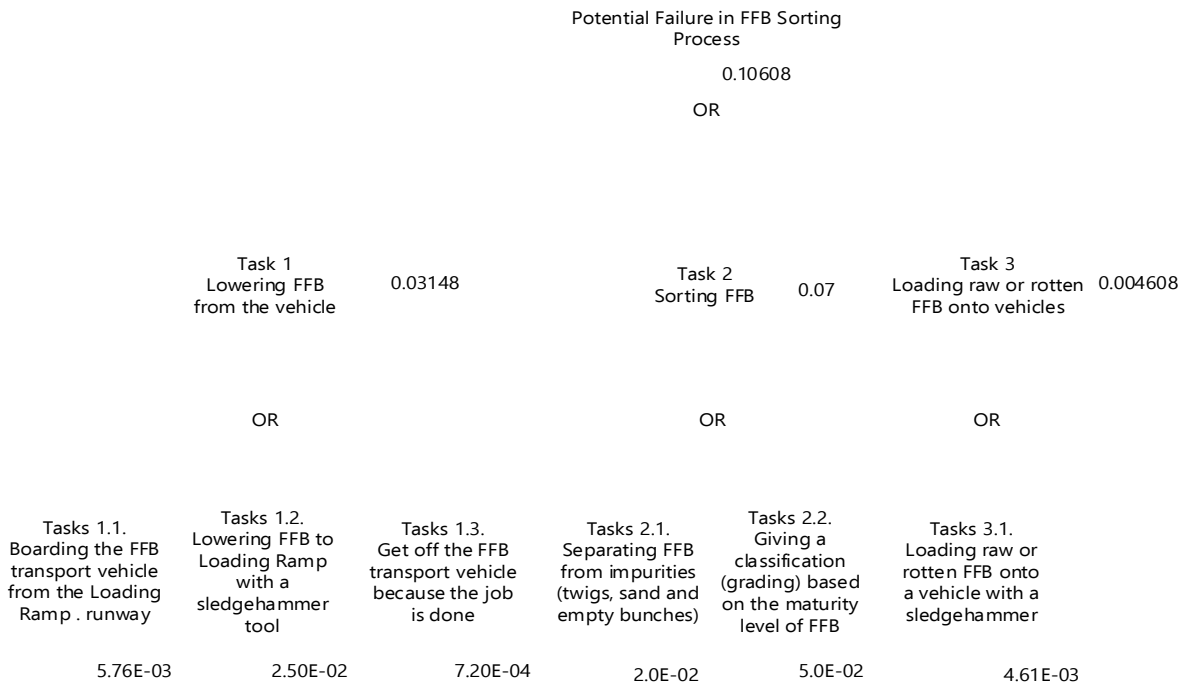

Figure 7. Result of FTA Method for FFB Sorting Process

Department. The results of the HEP measurement have 3 tasks in the FFB Sorting Department. The HEP value using the HEART method through measurement has a higher value than the HEP CREAM value. Task 2 in the FFB sorting process has a fairly high HEP value in both the HEART and CREAM methods.

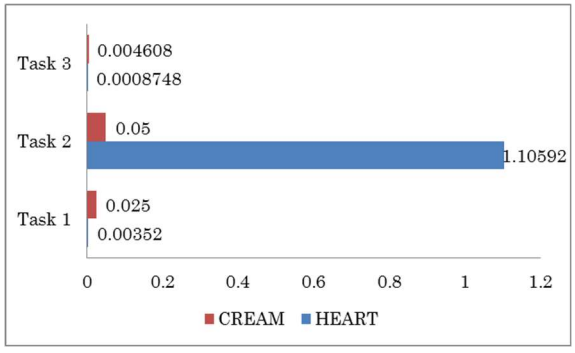

Figure 8. Comparison of HEP Measurement Results HEART and CREAM Methods in the FFB Sorting Department

This is influenced by several things. The use of the HEART method defines the type of work in an activity type through the determination of a generic task (Pan & Wu, 2020). The categories displayed by the Generic Task have been able to describe the level of difficulty of a job well. However, this HEART method cannot explicitly conclude the factors that cause the probability of human error. The CREAM method is the use of its cognitive function. This is indicated by dividing tasks that have a probability of failure of action based on cognitive functions such as observation, interpretation, planning and execution.

IV. Conclusion

Based on the processing and analysis of the results, it can be concluded as follows: the HEP analysis using the HEART method in the FFB Sorting Department is 1.1103148 with the largest rework potential in task 2 of 1.10592. HEP analysis using the CREAM method was obtained for the Sorting Department of 0.10608. Both of these lines are included in the opportunistic control mode.

Comparison of measurement results using the HEART and CREAM methods there are significant differences. The HEART method has a higher HEP value than the CREAM method. This is

influenced by the determination of the generic task in the HEART method which describes the level of difficulty of a job well. In addition, further research is recommended to use time analysis to support the Human Reliability Assessment (HRA) Method.

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