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Human Reliability Assessment on RTG Operational Activities in Container Service Companies Based on Sherpa and Heart Methods

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Abstract:- Utilization of technology in various service activities and loading and unloading facilities at the International Container Terminal in Surabaya (ICT) causes increased interaction between humans and machines, one of which is the Rubber Tyred Gantry (RTG) device operated by the operator. A large number of RTG equipment used has a very high potential for work accident hazards. The recapitulation of accident data for 2015-2021 shows that there have been 1,074 accidents. Several accidents at ICT is caused by an error from the operation of the equipment or human error factor. The purpose of this study was to analyze the human reliability assessment on the operation of the RTG using the Systematic Human Error Reduction and Prediction (SHERPA) and Human Error Assessment and Reduction Technique (HEART) methods, with primary data obtained through interviews with expert judgments. Based on the research that has been done, the probability value of the occurrence of human error in the operation of the RTG found the highest HEP value results, namely in subtasks 2.4 and 4.3 with a HEP value of 0.496 each and also with a total reliability value (Rm) in the operating process resulting in an Rm value < 0.5 which indicates the reliability of the operator is still low in carrying out the entire process. The recommendations given include a refreshment program and socialization related to work instructions to RTG operators.

Keywords:- *Accident; Human Error Assessment and Reduction Technique; Human Reliability Assessment; Rubber Tyred Gantry; Systematic Human Error Reduction and Prediction.*

I. INTRODUCTION

Rubber Tyred Gantry (RTG) is one of the equipments used in the process of loading and unloading containers at the stacking yard at the International Container Terminal in Surabaya (ICT). In operation, the position of the RTG Operator's workspace is at an average height of 25-60 meters above sea level, with the working position in the cabin not ergonomic. One of them is bending, the movement of the hands is raised, and so on, besides the farther the position of the body from the center of gravity of the body, the risk of muscle complaints and the impact on fatigue (Amalia., et al., 2017). The impact of fatigue experienced by operators is important to note because it can have an impact on decreasing work productivity and decreasing work concentration. The large number of RTG equipment used for loading and unloading activities has a very high potential for work accident hazards. This is following the results of the accident data recapitulation from ICT in 2015-2021 shows that there have been 1,074 accidents. Several accidents at ICT is caused by an error from the operation of the equipment or human error factor.

According to Henrich's theory (Kairupan., et al, 2019) says that 80% of work accidents are caused by unsafe actions. Humans as a factor causing accidents are often called human error. According to (Woods., et al, 2010) in his book entitled behind human error explains that human error is a category of potential causes for any unsatisfactory or successful event. In each process, the human element is unreliable and the solution to the problem of human error has a role to change people or roles in the system.

The scope of human error includes all humans involved in the production process starting from the highest leadership, design experts, engineering experts, equipment procurement officers, supervisors, operators, and everyone involved in production. This human error can affect the results or output of the work done. (Pamuka & Susanto, 2018) categorizes factors that can affect the results of human work into two groups including:

- Self (individual) factors consist of attitudes, traits, values of physical characteristics, motivation, age, gender, education, experience, and others.
- Situational factors of the physical environment, machinery and equipment, work methods, and others.

Human error can potentially cause work accidents. work accidents caused by human error can be given preventive action by identifying the Human Reliability Assessment (HRA) (Nurhayati., et al, 2017). HRA is a qualitative and quantitative method to measure the human contribution to risk and determine the level of reliability of humans who are members of a system. In total there are 72 tools in human reliability that are potentially used, of which 37 methods are still under investigation and 35 methods that have been investigated can be used in measuring human reliability in the context of K3LL (Bell & Holyord, 2009). Before conducting a human reliability assessment analysis, the first step that must be done is to analyze the work stages of the operator. The stages of this work can be analyzed using Hierarchical Task Analysis (HTA). HTA produces an overview in the form of a hierarchy of jobs and sub-jobs. In HTA also known plans that explain the sequence and conditions of work carried out. HTA can be in the form of text or diagrams (Pamuka & Susanto, 2018).

One of the HRA methods is SHERPA (Systematic Human Error Reduction and Prediction) and HEART (Human Error Assessment and Reduction Technique). The SHERPA method is a qualitative method to analyze human error by using a basic level task as input. The task that will be analyzed will then be broken down first, then from each basic level task, human errors will be predicted that will occur in it. According to Stanton (Putro et al., 2015), SHERPA was developed as a technique for predicting human error which also analyzes work and identifies potential solutions to overcome errors in a structured way.

While the HEART method is a method that can be used to evaluate the probability of the occurrence of human error during the completion process of a specific job and provide advice to users (either engineer or ergonomic) about reducing errors when doing work (Kirwan, 1994). The main function of the HEART method is to classify tasks into the general form and determine a nominal value to find the value of human unreliability. Excellence in finding the value of human unreliability is following the problems to be solved in this study. In addition, this method is also based on the general principle that for every task in daily life there is a possibility of failure. Each task affects various levels of conditions that cause errors or what are called Error Producing Conditions (EPC) (Williams, 1986). The result of this HEART method is the total value of the possibility of failure or Human error probability (HEP) and the factors that contribute to the occurrence of errors from the operation of the RTG.

The probability of reliability of human reliability is the opposite of HEP. In addition, the reliability level classification process is obtained with the Generic Task Type (GTT) tool. In GTT, the types of work are categorized based on the task and the nominal value of human unreliability along with the range of each task. The following is the classification of GTT according to (Bell & Holyord, 2009):

Task Category		**Nominal Human Unreliability**	**Range**
A	Not used to it at all, run fast without knowing the possible consequences	0,55	(0,35-0,97)
B	Replace or restore the system to a new or original form by one's own efforts without supervision or procedure	0,26	(0,14-0,42)
C	Complex work that requires a high level of understanding and skills	0,16	(0,12-0,28)
D	Simple jobs that are done quickly or with little attention	0,09	(0,06-0,13)
E	Routine, very practical, fast work involving relatively low skill	0,02	(0,007-0,045)
F	Restoring or replacing a system to its original or new form by following a procedure with several checks	0,003	(0,0008-0,007)
G	Very familiar, well designed very practical, routine work that occurs several times per hour, done to the highest possible standard	0,0004	(0,00008-0,009)
H	Responds correctly to the same directive system, where there are additions or an automated monitoring system that provides the accurate interpretation of system stages	0,00002	(0,000006-0,0009)
M	There is no such situation above	0,03	(0,008-0,11)

Table 1: GTT In HEART Method

Based on table 1, it can be seen that the results of the HEP calculation using the HEART method can be calculated the human reliability value of each existing GTTs. So that the results obtained from the calculations can be used to assess the extent to which the performance of human reliability in the work system and evaluate what improvements can be made based on the probability of failure of each activity. Where if the value of Rm <0.5 means the value of the reliability of the work in carrying out its work instructions is still low. And if the value of Rm> 0.5 means that the reliability value of workers in carrying out their work instructions is high (Williams, 1986).

In this study, human error analysis will be carried out in the operation of the RTG equipment because it has the highest working frequency in the loading and unloading of containers. Human error analysis was carried out using the SHERPA and HEART methods, by classifying human error tasks, Generic Task Type (GTT), and HEP calculations to probability calculations. The final result in the form of recommendations obtained from the results of the analysis is used as a control and prevention of work accidents caused by human error events.

II. METHOD

This research is equipped with steps from the completion stage in order to obtain conformity with the purpose of the analysis so that it can be understood systematically. The initial stage of this research is a survey and identification of accident data on the operation of the RTG at ICT to get the main problem, setting goals and benefits of research, which is related to the process of analyzing human error in the operation of the RTG as well as recommendations for controlling and preventing accidents due to human error. Based on the problems obtained from the initial identification, literature studies and also field studies were carried out to obtain methods that were in accordance with the existing problems.

The method used to analyze human error is the SHERPA and HEART methods. In conducting the human error assessment, this is done together with expert judgment. Interviews conducted together with expert judgment can be carried out according to research (Pasman & Rogers, 2020). The initial step taken is to analyze the work stages using HTA which is then continued using the SHERPA method to analyze human error by using the basic level task as input. The task to be analyzed will then be broken down first, then from each basic level task, human errors will be predicted that will occur in it. The analysis is continued using the HEART method to classify tasks into the general form and determine the nominal value to find the value of human unreliability.

The result of the HEART method is the total value of the possibility of failure or Human error probability (HEP) and the factors that contribute to the occurrence of errors from the operation of the RTG. Therefore, from the results of the HEP calculation, we can continue to calculate the human reliability value of each existing GTTs. The results obtained from the calculations can be used to assess the extent to which the performance of human reliability in the work system and evaluate what improvements can be made based on the probability of failure of each activity.

III. MATERIAL

The data collected to perform this human error analysis is primary data resulting from discussions with expert judgment in the form of Hierarchical Task Analysis (HTA) to produce a hierarchical description of jobs and sub-jobs based on RTG operating work instructions. Other primary data are task classification, GTT, identification of human error, consequence analysis, human error probability (HEP), risk analysis, and remedy analysis. While the secondary data needed for this research are work instructions from the operation of the RTG and work accident data from the company. The following is the HTA that is made based on the implementation of monitoring operational activities and work instructions in the company for the operation of the RTG:

Task Analysis	Sub Task Analysis
Operator Preparation before operating the RTG	Operator has defecated and urinated Conduct attendance and safety talk before operating CC Using PPE (safety helmet, fluorescent vest, and safety shoes) Coordinate with the RTG Superintendent regarding the RTG to be operated and work activities in the work area
Initial preparation for RTG operation	Checking the condition of the machine at the bottom Turn on the RTG engine and let it sit for + 5 minutes Carrying out checks before and during the operation of the RTG and filling out a checklist Checking RTG Movement of the trolley system, hoist on spreader Turn on the lighting at night, dawn, an evening when the view is not good, rain or fog
Coordination between work teams	Listening to the signal from the tower officer over the radio Monitoring existing work orders on the VMT machine Verify the work area with the field supervisor to ensure the RTG work area is safe from queues/trailer obstructions parked on the RTG lane
RTG Operation	Doing container stacking receiving, delivering, unloading and load according to VMT instructions Do the hoist up movement as much as possible maybe while crossing the heights stack containers that don't dismantled Doing container stacking according to the markings that have been provided Confirm with VMT for every move/movement container properly slots and blocks
Completion of RTG operatio	Handing over a written damage report to the superintendent and the operator who replaces it Log Out VMT Shutting Down the RTG Engine

Table 2: HTA Operation Work RTG

Table 2 shows the HTA operation of the RTG which describes how humans carry out their duties so that they can be responsible for their work, explain what is done and the equipment used and things that need to be known in an analysis.

IV. RESULTS AND DISCUSSION

Identification of human error to analyze the possibility of failure that occurs based on Hierarchical Task Analysis on the operation of the RTG is carried out through direct observations at work and discussions with expert judgment. Direct observations were made to determine the error mode by determining the error description analysis that occurred in the error mode in the SHERPA table. In conducting this identification and analysis, the researcher and expert judgment carried out direct observation of the implementation of activities in the RTG work area during the period from August 1 to October 31, 2021, and recapitulation of accident events from 2015 to 2020. Following are the results of direct observations obtained:

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No	**Job Step**	**Error Mode**	**Errors that Occur**
1	2.3 Carrying out checks before and during the operation of the RTG and filling out a checklist	A9	RTG operators who do not perform inspections before and during operation can result in equipment damage not being identified so that if the RTG is still operated there is a potential for accidents to occur.
2	2.4 Checking the RTG movement of the trolley system, hoist on the spreader	A7	The RTG operator does not check the hoist, spreader, and trolley systems, resulting in no identified movements according to orders
3	3.3 Verify the work area with the field supervisor to ensure the RTG work area is safe from queues/trailer obstructions parked on the RTG lane	C4	The RTG operator verifies the field Supervisor to ensure that the RTG area on the farside is safe for movement/gantry
4	4.2 Make the maximum possible hoist up movement while crossing the unloaded container stack height	A3	The RTG operator does not perform the hoist-up movement as much as possible, this will result in collisions between the containers being handled and have an impact on the occurrence of work accidents.
5	4.3 Doing container stacking according to the markings that have been provided	A5	The RTG operator does not stack the containers according to the markings, which will have an impact on the arrangement of the stacking of containers being irregular and there is a risk that the stack of containers will topple over
6	5.1 Handing over a written damage report to the superintendent and the operator who replaces it	I1	The RTG operator does not report any damage to the RTG when operating it will result in a malfunction of the tool and the risk of a work accident
Total Error			6 Action Error

Table 3: The Results Of Direct Observation Of Errors in The Operation Of The RTG

From the results of observations that have been made on the activities of the RTG operators while operating the RTG errors that occur in the operation of the RTG if control measures are not taken immediately can cause risks, including disruption of container B/M service activities in the stacking field, the risk of work accidents occurring during the operation of the RTG. The next step is to perform recovery analysis, sequential probability and criticality level for each identified work step error. The following is a table of the results of the analysis that has been carried out.

No	Job Step	Recovery	Probability	Critical Level
RTG Operation				
1	2.3 Carry out checks before and during RTG operation and fill out checklists	Immediate	M	!
2	2.4 Checking the RTG movement of the trolley system, hoist on the spreader	Immediate	M	!
3	3.3 Verify the work area with the field supervisor to ensure the RTG work area is safe from queues/trailer obstructions parked on the RTG lane	Immediate	M	!
4	4.2 Make the maximum possible hoist up movement while crossing the unloaded container stack height	Immediate	H	!
5	4.3 Doing container stacking according to the markings that have been provided	Immediate	H	!
6	5.1 Handing over a written damage report to the superintendent and the operator who replaces it	Immediate	M	!

Table 4: Recovery, Probability, and Criticality Analysis on RTG Operation

Based on the results of the recovery analysis, probability, and criticality of the operation of the RTG, the following results are obtained:

A. Recovery
   1) Immediate : 6 step jobs
   2) None : 0 step jobs

B. Probability
   1) Low : 0 step jobs
   2) Medium : 4 step jobs
   3) High : 2 step jobs

C. Criticality Level
   1) Unacceptable loss : 6 step jobs
   2) Acceptable loss: 0 step jobs

The next step is error quantification to obtain the Human Error Probability (HEP) value, which is calculated using the HEART method, including:

1. Generic Task Type (GTT) Analysis
   The following are the results of grouping work step errors into 9 types of work in the GTT table and the value of human unreliability.

No	Job Step	GTT	Nominal Human Unreliability
RTG Operation			
1	2.3 Carry out checks before and during RTG operation and fill out checklists	C	0,16
2	2.4 Checking the RTG movement of the trolley system, hoist on the spreader	C	0,16
3	3.3 Verify the work area with the field supervisor to ensure the RTG work area is safe from queues/trailer obstructions parked on the RTG lane	F	0,003
4	4.2 Make the maximum possible hoist up movement while crossing the unloaded container stack height	C	0,16
5	4.3 Doing container stacking according to the markings that have been provided	C	0,16
6	5.1 Handing over a written damage report to the superintendent and the operator who replaces it	D	0,09

Table 5: GTT Analysis And The Value Of Human Error Probability

Based on the results of the analysis, in the operation of the RTG, generic task categories were obtained which were adjusted to the GTT in the HEART method, including:

- Category C: Work that is complex and requires a high level of understanding and skills, including sub-tasks 2.3, 2.4, 4.2, 4.3 with a human unreliability score of 0.16. This means that the average failure rate is estimated at 16 times out of 100 activities.
- Category D: Work that is quite simple, done quickly, or requires little attention, including sub-task 5.1 with a human unreliability value of 0.09. This means that the average failure rate is estimated at 9 times out of 100 activities.
- Category F: Restoring or shifting the system to its original or new condition by following the procedure, with several checks, including sub-task 3.3 with a human unreliability value of 0.003. This means that the average failure rate is estimated at 3 times out of 1000 activities.

2. Analysis of Error Producing Conditions (EPCs)
The results of the analysis show the categories of Total Effect (fi) values on the operation of the RTG, including:
   a. The Total Effect (fi) with a value of 4 is on the RTG tasks 2.4 and 4.3, namely the condition that causes the error is a mismatch between the imagined risk and the actual risk.
   b. The Total Effect (fi) with a value of 2.5 is on the RTG 3.3 task, that is, the condition that causes the error is that there is no difference in the input information for careful checking.
   c. The total effect (fi) with a value of 1.1 is on the RTG task of 2.3, 4.2, 5.1, namely with conditions that cause errors, namely prolonged laziness or low mentality to do work that often occurs.

3. Calculation of Human Error Probability
The following is the calculation of HEP on RTG operation:

Task	Sub Task	HEP
1. The initial preparation for RTG operation	2.3	0,1712
	2.4	0,496
2. Coordination between work teams	3.3	0,0075
3. RTG Operation	4.2	0,1712
	4.3	0,496
Completion of RTG operation	5.1	0,0963

Table 6: Recap of HEP Calculation Results On RTG Operation

Based on table 6 in the operation of the RTG, there are two sub-tasks with the highest HEP values, namely in sub-tasks 2.4 and 4.3, and the lowest values in sub-tasks 3.3. In calculating the HEP, the results obtained are influenced by three assessment factors determined through a discussion process with expert judgment, namely, GTTs assessment, EPCs assessment, then APOA assessment. when the greater the three value factors, the greater the HEP value that will be generated.

4. Probability calculation
 The following are the results of the calculation of R and Rm on the RTG operation work:

Task Step	HEP	Fi = 1 - ∏ (1-HEP)	Ri = 1 - Fi
2.3	0,1712	0,1712	0,8288
2.4	0,496	0,496	0,504
3.3	0,0075	0,0075	0,9925
4.2	0,1712	0,1712	0,8288
4.3	0,496	0,496	0,504
5.1	0,0963	0,0963	0,9037
Total System Reliability (Rm) (Rm = ∏ Ri)			0,156500365

Table 7: Calculation of F, R, and Rm in RTG . Operation

From the results of the calculation of the total reliability value (Rm) on the operator in the operation of the RTG which is shown in table 6. The low reliability of the operator in the operation of the RTG can result in a large potential for operator failure/human error so it can result in workplace accidents that can cause serious losses. physical and material, so it is necessary to give recommendations so that the reliability of the RTG operator becomes high with a value of Rm> 0.5 so that the potential for human error is lower and the potential for workplace accidents in the operation of the RTG is also lower.

V. CONCLUSION

Based on the results of the HRA research using the SHERPA and HEART methods in the operation of the RTG, it was concluded that the results of error identification using the SHERPA method showed that 6 sub-task errors resulted in work accidents in the operation of the RTG and must be immediately restored, namely in sub-task 2.3; 2.4; 3.3; 4.2; 4.3; and 5.1. In addition, there are 2 sub-tasks with high probability, namely in sub-tasks 4.2 and 4.3, and 6 sub-tasks with an unacceptable level of criticality, namely in sub-tasks 2.3; 2.4; 3.3; 4.2; 4.3; and 5.1. After calculating the HEP value in the RTG operation, the highest HEP value was found in subtasks 2.4 and 4.3 with a value of 0.496, this means that the probability of a human error occurring in the subtask is 49.6%, namely when carrying out container stacking activities according to the markings and inspection of hoist, spreader and trolley systems which is a complex activity and requires a high level of understanding and skill. While the lowest HEP value is found in sub-task sub-task 3.3 with a value of 0.0075 or 0.75%, namely when verifying the work area with the field supervisor to ensure the RTG work area is safe from queues/trailer obstructions parked on the RTG line.

The value of total reliability (Rm) in the operation of the RTG was obtained at 0.156500365, which indicates that the reliability of the operator in carrying out work instructions is low because the value of Rm<0.5. So that the recommendations that can be given include carrying out a refreshment program to all RTG operators, providing socialization to all RTG operators to comply with work instructions and giving strict sanctions to operators when violating work instructions, as well as revising work instructions at points that are still unclear. to be more detailed and measurable so as not to result in various kinds of perceptions.

Suggestions that can be given by researchers for future research is when the process of analyzing human error is better than the data on events that exist in the company. In addition, the process of determining hazard recommendations can use a risk control method so that the results obtained are more structured and systematic.

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