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Human Error Analysis on Rubber Tyred Gantry Operation Using CREAM Method

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Abstract

The container terminal facility service company produces loading and unloading of containers which are supported by loading and unloading equipment, one of loading and unloading equipment that has an important role is Rubber Tyred Gantry (RTG) with high operating hours, so potentially for accidents. When preliminary research was conducted on a container service company by collecting accident data of RTG operation, The data generated by the accident occurrence of RTG operation in the period of 4 years from 2018-2021 there were 75 accidents. Further analysis conducted about causes of RTG accidents based on 3 factors, human factor, equipment factor, and environmental factor, The result is human factor the main cause with a percentage of 75%. So in this research it is necessary to analyze human error in the operation of the RTG. This research conducted a human error analysis using the Human Reliability Assessment (HRA) method, namely CREAM with the aim of knowing the highest Cognitive Failure Probability (CFP) value and then making improvements to reduce and prevent human errors. After conducting a human error analysis using the CREAM method on the operation of the RTG generated the highest CFP value is in the subtask 3.3, 4.4, and 5.3 with a value of 0.0047. Repair recommendation action is given are revisions to WI, providing refreshment to RTG, increasing safety patrols.

Keywords*:HRA, CREAM, HEP, Human Error, RTG*

1. Pendahuluan

1.1 Background

The container terminal facility service company produces loading and unloading of containers which supported by loading and unloading equipment, then one of loading and unloading equipment that has important role is Rubber Tyred Gantry (RTG) with high operating hours and total of 30 units RTG crane, so this has the potential to cause work accidents. When preliminary research was conducted on the accident of RTG operation within a period of 4 (four years from 2018-2021, then generated data as follows Figure 1.

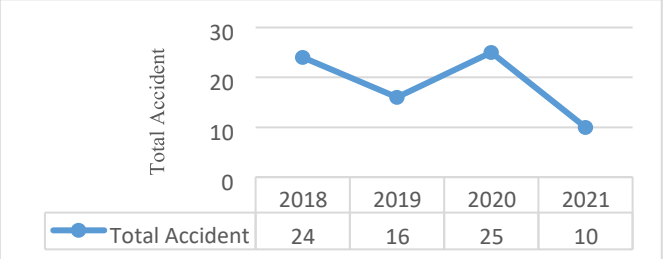

Figure 1. Rtg Accident Data Recapitulation For 2018-2021

Figure 1 shows that every year there are accidents in RTG operations starting from 2018-2021 which fluctuate and the highest number of accidents in RTG operations occurred in 2020 there were 25 accidents. Then further analysis is carried out about the basic causes of accidents based on three factors, namely human, equipment, then environment. According to (Suwignyo et al., 2018) an accident can occur due to several factors, namely human factors, environmental factors, and equipment factors. So from the RTG accident analyzed based on these three factors, human factor, environmental factor, and equipment factor, then generated data can be seen in Figure 2. [1]

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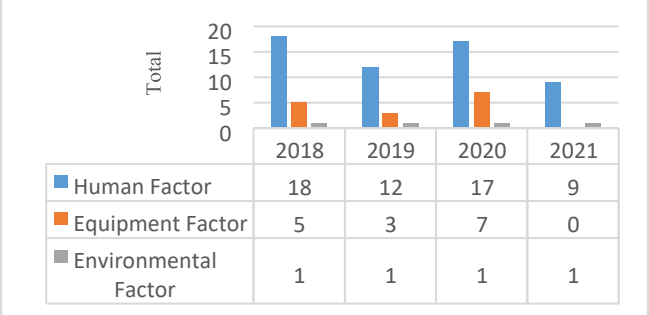

Figure 2. *Number Of Accidents Every Year Based On 3 Factors Causing Rtg Accidents In 2018-2021*

Can be seen in Figure 2 that the human factor is the highest causing accidents every year. Then a recapitulation is carried out on each factor causing accidents in the operation of the RTG from 2018 to 2021, then generated data is presented in the form of a pie chart which can be seen in figure 3.

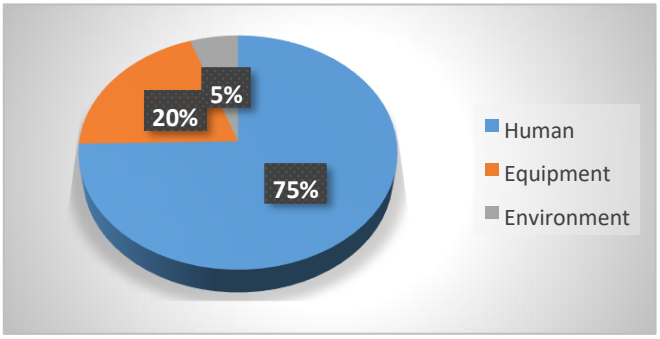

Figure 3. Total And Percentage Based On 3 Factors Causing Rtg Accidents In 2018-2020

Can be seen in Figure 3 percentage of accidents due to human factors 75%, equipment factors 20%, environmental factors 5%. So from these data it is known that the main factor in the occurrence of work accidents in the operation of the RTG is the human factor. According to Swain in (Kirwan, 1994) human error is a series of human actions that are beyond tolerance or failure to act, then also according to (Shaputra et al., 2021) error is a human error in doing a job. So from this it can be concluded that the main cause of RTG work accidents is caused by human error/failure or human error with the percentage of accidents causing 72%.

The known accident data is that 75% of accidents in RTG operation are due to human error. These work accidents can hinder the production process of loading and unloading containers and potentially accidents or even increase of accidents in the operation of RTG in the future which can cause losses to company so that it is necessary to identify work accidents by analyzing human error which is the main cause of accidents in the operation of the RTG and then providing recommendations for improvement.

Performing human error analysis on the RTG operation using one of the HRA methods, namely by using the Cognitive Reliability and Error Analysis Method (CREAM) method. CREAM is a technique used to assess human reliability which aims to evaluate the possibility of errors made by humans throughout the completion of certain tasks. CREAM's quantitative approach is divided into two stages, namely the basic method and the extended method. At the basic method stage, initial testing is carried out on human interaction. Testing is carried out on the stages of the overall task and the main tasks carried out by humans. In the extended method stage to see an action or part of a task where there is a need for more detail (Hollnagel, 1998). The advantages of the CREAM method are that it has well-defined methods, classification schemes, and cognitive models. The greatest strength of the CREAM method applied to analysis

is its ability to anticipate certain errors. These particular errors may be overlooked in other HRA methods. The type of cognitive function failure causes the analysis to consider the type of error that may occur for each action (Forester et al., 2012).

The purpose of this research was to determine the value of Human Error Probability (HEP) on the operation of the RTG using the CREAM method then take corrective steps to prevent and reduce work accidents caused by human error.

1.2 Formulation Of The Problem

Based on the background, the problem formulations in this research are :

1. How to determine Cognitive Failure Probability (CFP) value on Rubber Tyred Gantry operation using CREAM?
2. How is the analysis result of Cognitive Failure Probability (CFP) value on Rubber Tyred Gantry operation using CREAM ?
3. How is the appropriate recommendation to reduce human error probability on Rubber Tyred Gantry operation?

1.3 Research Objectives

The objectives to be achieved from this research are :

1. Determine Cognitive Failure Probability (CFP) value on Rubber Tyred Gantry operation using CREAM
2. Analysis result of Cognitive Failure Probability (CFP) value on Rubber Tyred Gantry operation using CREAM
3. Determine appropriate recommendation to reduce human error probability on on Rubber Tyred Gantry operation

2. Study of Literature

2.1 Human Reliability Assessment (HRA)

Human Reliability Analysis is a method used to calculate the human contribution to risk qualitatively and quantitatively (Bell & Holroyd, 2009). Bell & Holroyd (2009) conducted a review of the Human Reliability Assessment methods, of which 72 Human Reliability Assessment methods were taken, but only 35 were further investigated because they were considered to have potential relevant to the main OHS hazards.

2.2 Hierarchical Task Analysis (HTA)

The HTA is, as its name suggests, a hierarchical approach. It describes the task from its top-level goals down to the level of individual operations (Kirwan, 1994). HTA generates a summary in the form of a hierarchy of jobs and sub-jobs. HTA is also aware of the plan to explain the process and conditions of the work being carried out (Pamuka & Susanto, 2018).

2.3 Cognitive Reliability and Error Assessment Method (CREAM)

CREAM is a human reliability assessment method that aims to assess the possibility of errors made by humans while performing certain tasks. CREAM's quantitative approach can be divided into two stages, namely the basic method and the extended method. At the basic method stage, initial testing is carried out on human interaction. Testing is carried out on the stages of the overall task and the main tasks carried out by humans. In the extended method stage to see an action or part of a task where there is a need for more detail (Hollnagel, 1998).

3. Research Methodology

This research begins with collecting data first, the data is divided into two, namely primary data consisting of expert judgment and observations on the operation of the RTG then TABLE 1. HTA OF RTG OPERATION (SEQUEL) secondary data consisting of operational accident data for the RTG 2018 - 2021 and IK operation of RTG. Then after the data is collected, the data is processed using the CREAM method. The CREAM method is divided into two stages, basic method and extend method.

The basic method steps consist of making a Hierarchical Task Analysis (HTA) with expert judgment to explain the stages in the operation of the RTG. Then carry out a Common Performance Condition (CPC) assessment on the operation of the RTG, in conducting the CPC assessment it is carried out with expert judgment then the results of the CPC

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assessment are used to determine the probable control mode so that the probability of failure of the general action on the operation of the RTG is generated.

The extended method stage begins with developing cognitive aspects of each RTG operation subtask carried out with expert judgment, the assessment of the cognitive aspect development becomes the basis for determining the possibility of cognitive function failure at a later stage. Then the second step is to determine the cognitive failure function and determine the nominal value of the cognitive failure function in each RTG operation subtask, assessed with expert judgment. And the last step is determine CFP, at this stage the first thing to do is to assess the effect of CPC on cognitive failure where the assessment of the CPC effect has been obtained at the basic method stage with the output obtained, namely the weighting factor, then the multiplication operation between the weighting factor and nominal CFP that has been obtained in the previous stage so that CFP values are generated for each subtask of RTG operation, then provide a discussion and provide conclusions from the research result.

4. Research Result

4.1 Basic Method

This stage aims to assess the overall reliability of performance on operation of RTG. The steps of the basic method include :

a. Hierarchical Task Analysis (HTA)

Hierarchical Task Analysis (HTA) aims to analyze the steps in the operation of the RTG. HTA is a human relationship with work equipment in a work process so that the stages of work carried out by humans are known. HTA describes the stages of work very clearly from the start of the operation to the end of the operation. In making HTA the operation of the RTG is presented in the table so that it is easy to understand where in the table there are sequences of work tasks and work subtasks where subtasks are details of a task. With the result shown in Table 1.

Table 1. HTA Of RTG Operation

Task Analysis	Subtask	
Preparation RTG Operator	1.1	Use work uniforms and PPE
	1.2	Conduct attendance and operator's cabin
Pre-Operation RTG	2.1	perform a ground level check
	2.2	Cleaning the cabin glass and operator's cbun
	2.3	Wear a seat belt
	2.4	Perform checks before and during operation with the available checklist
	2.5	Check engine condition/failure indication
	2.6	Start the engine and let it sit for 5 minutes
	2.7	Turn on VMT and log in according to the name and PIN have given by the company
	2.8	Check all Movement (Trolley, hoist, gantry and spreader)
	2.9	Turn on the RTG lights when the viewing conditions are not good, rain/fog, the electricity is off
Perform Receiving, Delivering,	3.1	Perform work orders (receiving, delivering, loading and unloading containers) as shown on the VMT screen

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Unloading, and Loading activities	3.2	Verify that the truck chassis twist lock has been opened before the container is hoisted up
	3.3	Perform container stacking by doing a full hoist when the trolley passes the container stack
	3.4	Perform container stacking according to the markings that have been provided
Perform Gantry	4.1	Viewing CCTV on the far side
	4.2	Perform trolley move to the far side and make sure the conditions are safe
	4.3	Perform gantry
Perform Crossing	5.1	Coordinate with the superintendent RTG
	5.2	Checking whether the wheels are in a parallel position
	5.3	Perform crossing guided by the Field Supervisor and coordinate about the crossing path
Post RTG Operation	6.1	Log Out VMT immediately after finishing work
	6.2	Doing Hoist Up Full, Turning off the radio and AC, Shut Down the Machine
	6.3	Hand over the damage report after completion of work to the superintendent and the operator who replaces it

Table 1 is the result of hierarchical task analysis of RTG operation work which has 6 main tasks with details, task 1 preparation RTG operator consists of 2 subtasks, task 2 pre operation RTG consists of 9 sub tasks, task 3 performs receiving, delivering , loading and unloading activities consists of 4 subtasks, task 4 perform gantry consisting of 3 sub tasks, task 5

perform crossing consists of 3 subtasks, task 6 post-RTG operation consists of 3 subtasks. The HTA that has been made with the expert judgment is then needed to assess the probability of human error on each subtask of RTG operation with CREAM method

b. Assess Common Performance Condition (CPC)

The next stage is to conduct an assessment of the CPC, CPC assessment consists of nine assessments carried out together with expert judgments, the results of which can be used to determine the general condition about RTG operation, with the results shown in Table 2.

Table 2. CPC Of RTG Operation

CPC Name	Level	Effect
Adequacy of organization	Very efficient	**Improved**
Working condition	Compatible	**Not significant**

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CPC Name	Level	Effect
Adequacy of MMI and operational support operational	Supportive	**Improved**
Availability of procedures / plans	Appropriate	**Improved**
Number of simultaneous golas	Matching current capacity	**Not significant**
Available time	Temporarily inadequate	**Not significant**
Time of day (circadian rhythm)	Day-time (adjusted)	**Not significant**
Adequacy of training and experience	Adequate, high experience	**Improved**
Crew collaboration quality	Very efficient	**Improved**

Table 2 can be seen that the CPC effects are 5 improved, 4 not significant, and 0 reduced, then these results will be used to determine the probable control mode in the next step and used in determining the weighting factor in the extended method.

c. Determining the Probable Control Mode

Table 2 is known as the result combination of CPC effects that there are 5 improved and 0 reduced, resulting in probable control mode in strategic control which can be seen in Figure 1.

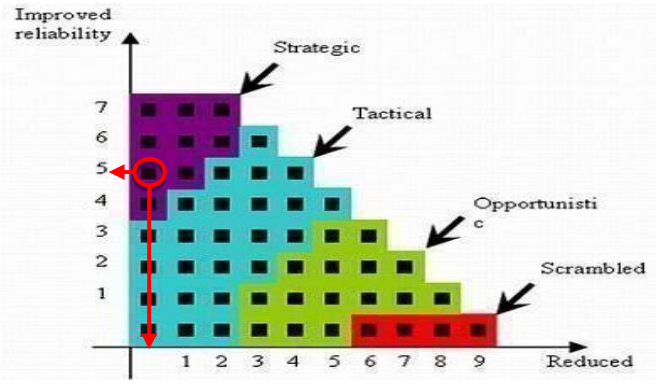

Figure 4. Relationship Between Cpc Results And Control Mode

Then from the results of the probability control mode is the strategic control type then generated probability of action failures interval of 0.5E-5<p<1.0E-2 which can be seen in Table 3.

Table 3. Control Modes And Probability Intervals

Control mode	Reliability Interval(probability of action failures)
Strategic	0.5 E-5 < p <1.0 E-2

Tactical	1.0 E-3 < p <1.0 E-1
Opportunistic	1.0 E-2 < p <0.5 E-0
Scrambled	1.0 E-1 < p <1.0 E-0

4.2 Extend Method

This stage aims to determine the error probability value of each task of the RTG operation. The steps of extend method include:

a. Build A Cognitive Demand Profile

At this stage, an assessment of the cognitive aspects used in each subtask of RTG operation which assessed with expert judgment, then a cognitive activity demand matrix is generated with a percentage of observation activity of 16.67%, interpretation activity 20%, planning 0%, and execution 63.33 % it can be seen in Table 4. So it can be seen that the RTG operation work is dominated by execution activities.

Table 4. Generic Cognitive Activity By Cognitive Demand Matrix Of Rtg Operation

Sub task	**Cognitive Activity**	**COCOM Function**			
		Obs	**Int**	**Plan**	**Exe**
1.1	Execute				X
1.2	Communicate				X
2.1	Verify	X	X		
2.2	Execute				X
2.3	Execute				X
2.4	Record		X		X
2.5	Verify	X	X		
2.6	Execute				X
2.7	Execute				X
2.8	Verify	X	X		
2.9	Execute				X
3.1	Execute				X
3.2	Verify	X	X		
3.3	Execute				X
3.4	Execute				X
4.1	Execute				X
4.2	Execute				X
4.3	Execute				X
5.1	Communicate				X
5.2	Verify	X	X		
5.3	Execute				X
6.1	Execute				X
6.2	Execute				X
6.3	Communicate				X
Total		**5**	**6**	**0**	**19**
Percentage (%)		**16,67**	**20**	**0**	**63,33**

Then the results from the cognitive demand matrix for each subtask which have been shown in Table 4 become a reference to identifying the likely cognitive function failure at the next stage.

b. Identify Likely Cognitive Function Failure

This stage, determine the cognitive function failure on each subtask of the RTG operation by referring to the cognitive aspects used in the previous stage, then it is produced that the cognitive aspects that affect failure are interpretation with a percentage of 20.83% and execution with a percentage of 79.1% which can be seen in Table 5. so it can be seen that the failure of RTG operation is dominated by execution error.

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Table 5. Generic Cognitive Function Failure Of Rtg Operation

Subtask	Cognitive Activity	Obs. Error	Int. Error	Plan. Error	Exe. Error
1.1	Execute				E5
1.2	Communicate				E5
2.1	Verify		I2		
2.2	Execute				E5
2.3	Execute				E5
2.4	Record				E5
2.5	Verify		I2		
2.6	Execute				E5
2.7	Execute				E5
2.8	Verify		I2		
2.9	Execute				E5
3.1	Execute				E3
3.2	Verify		I2		
3.3	Execute				E5
3.4	Execute				E1
4.1	Execute				E5
4.2	Execute				E5
4.3	Execute				E5
5.1	Communicate				E5
5.2	Verify		I2		
5.3	Execute				E5
6.1	Execute				E5
6.2	Execute				E5
6.3	Communicate				E5
Total		**0**	**5**	**0**	**19**
Percentage (%)		**0**	**0,83**	**0**	**79,17**

After determining the cognitive function failure in each subtask of RTG operation, then determining the nominal value of CFP for each subtask of RTG operation, the result can be seen in Table 6.

Table 6. Nominal Cfp Of Rtg Operation

Sub Task	Error mode	Nominal CFP
1.1	E5	0,025
1.2	E5	0,025
2.1	I2	0,01
2.2	E5	0,025
2.3	E5	0,025
2.4	E5	0,027
2.5	I2	0,01
2.6	E5	0,026
2.7	E5	0,03
2.8	I2	0,01
2.9	E5	0,03
3.1	E3	0,0005
3.2	I2	0,01
3.3	E5	0,037
3.4	E1	0,003
4.1	E5	0,03
4.2	E5	0,03
4.3	E5	0,037

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5.1	E5	0,03
5.2	I2	0,01
5.3	E5	0,037
6.1	E5	0,03
6.2	E5	0,027
6.3	E5	0,03

The results from the nominal value of the CFP which can be seen in Table 6 then be used to determine the cognitive failure probability for each subtask of RTG operation at the next stage

c. Determining Cognitive Failure Probability

This first step is to determine the weighting factor of the CPC effect on cognitive failure in RTG operation, which the CPC value has been generated in the basic method. Then the weighting factor generated which is shown in Table 7.

Table 7. The Effects Of Cpc On Cognitive Function Failure

CPC name	**Level**	**COCOM function**			
		Obs	**Int**	**Plan**	**Exe**
Adequacy of organization	Very efficient	1,0	1,0	0,8	0,8
Working condition	Compatible	1,0	1,0	1,0	1,0
Adequacy of MMI and operational support operational	Supportive	0,5	1,0	1,0	0,5
Availability of procedures / plans	Appropriate	0,8	1,0	0,5	0,8
Number of simultaneous golas	Matching current capacity	1,0	1,0	1,0	1,0
Available time	Temporarily inadequate	1,0	1,0	1,0	1,0
Time of day (circadian rhythm)	Day-time (adjusted)	1,0	1,0	1,0	1,0
Adequacy of training and experience	Adequate, high experience	0,8	0,5	0,5	0,8
Crew collaboration quality	Very efficient	0,5	0,5	0,5	0,5
Total effect CPC		**0,16**	**0,25**	**0,1**	**0,128**

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Then the multiplication operation between nominal cognitive failure and the weighting factor to determine the CFP value for each subtask in the RTG operation with the resulting data shown in Table 8.

Table 8. Cognitive Failure Probability Of Rtg Operation

Subtask	Error Mode	Nominal CFP	Weight Factor	CFP
1.1	E5	0,025	0,128	0,0032
1.2	E5	0,025	0,128	0,0032
2.1	I2	0,01	0,25	0,0025
2.2	E5	0,025	0,128	0,0032
2.3	E5	0,025	0,128	0,0032
2.4	E5	0,027	0,128	0,0035
2.5	I2	0,01	0,25	0,0025
2.6	E5	0,026	0,128	0,0033
2.7	E5	0,03	0,128	0,0038
2.8	I2	0,01	0,25	0,0025
2.9	E5	0,03	0,128	0,0038
3.1	E3	0,0005	0,128	0,0001
3.2	I2	0,01	0,25	0,0025
3.3	E5	0,037	0,128	0,0047
3.4	E1	0,003	0,128	0,0004
4.1	E5	0,03	0,128	0,0038
4.2	E5	0,03	0,128	0,0038
4.3	E5	0,037	0,128	0,0047
5.1	E5	0,03	0,128	0,0038
5.2	I2	0,01	0,25	0,0025
5.3	E5	0,037	0,128	0,0047
6.1	E5	0,03	0,128	0,0038
6.2	E5	0,027	0,128	0,0035
6.3	E5	0,03	0,128	0,0038

Based on the calculation of error probability in the basic method, the CREAM method for RTG operation is in strategic control mode control with an interval of 0.5 E-5 < 1.0 E-2. So this is appropriate because all calculations of the extended method on the CFP value of each subtask which can be seen in Table 8 are generated in the interval value of 0.5 E-5 < 1.0 E-2 in the basic method. Due to this, the CREAM method in the basic method is used to determine the probability of human error in the whole work, while at the extend method it is used to determine the probability of human error in each work subtask.

Then it can also be seen from the analysis using the Cognitive Reliability and Error Analysis Method (CREAM) that RTG operations dominated by execution activities can be seen in Table 4 with a percentage of 63.33% then when conduct cognitive function failure analysis from the result is also known that the biggest failure is from execution error with a percentage of 79.17% can be seen in Table 5, this shows that the failure in the operation of the RTG was dominated by execution activities, then also at the highest CFP value in the execution aspect with the type of error E5, namely execution that was left behind, not carried out (negligence), including lack of understanding of tasks wich located in subtask 3.3. Perform container stacking by doing a full hoist when the trolley passes the container stack , 4.3 perform gantry, and 5.3 Perform crossing guided by the Field Supervisor and coordinate about the crossing path with CFP value of 0.0047 . The condition of execution error on the subtasks 3.3, and 5.3 because the RTG operator who works is not in accordance with the Work Instruction and in the subtask 4.3 when doing gantry where the operator should periodically look at CCTV not written in the work instructions.

5. Conclusion

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Based on the results of the research, it is known that the basic method of the Common Performance Condition (CPC) aspect assessment results in probable control mode of strategic control type, this means that the common performance condition supports the reliability of the operator in the operation of the RTG, then the extend method produces the highest Cognitive Failure Probability (CFP) values in subtask 3.3. Perform container stacking by doing a full hoist when the trolley passes the container stack , 4.3 perform gantry, and 5.3 Perform crossing guided by the Field Supervisor and coordinate about the crossing path with CFP value of 0.0047 and type of error is execution error (E5), namely execution that was left behind, not carried out (negligence), including lack of understanding of tasks.

Although in the basic method, probable control mode, the resulting mode is strategic control, which should improve the operator's reliability, but from the container service company data, it shows that the highest caused RTG operation accident was caused by human error, this happens because at the extend method stage it can be seen that at the highest CFP in subtask 3.3. Perform container stacking by doing a full hoist when the trolley passes the container stack , 4.3 perform gantry, and 5.3 Perform crossing guided by the Field Supervisor and coordinate about the crossing path; it is caused by an execution error in which the operator is negligent in doing work.

The improvement recommendation given is make revisions on WI by adding a subtask when doing gantry with an addition that is when doing gantry the RTG operator periodically looks at CCTV on the far side lane to ensure that the far side lane condition is free of obstacles, provide RTG refreshment to all operators on a regular basis and emphasize to comply with the applicable Work Instruction of Rubber Tyred Gantry operations at least once a year, then increase safety patrols with the safety team is always on guard in the field in turn to monitor so that there are no violations by RTG operators,.

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6. Research Result

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