RISK ANALYSIS AT SHIP TO SHORE (STS) CRANES IN CONTAINER TERMINAL OPERATIONAL SYSTEM OF A GREENPORT USING FAILURE MODE AND EFFECT ANALYSIS

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Abstract - *Globalization has led to a rapid increase in container movement in seaports. The more quantity and complexity of activities undertaken in the Port will increase risks primarily because of the displacement of containers that require high mobility. Attention to the security window also plays an important role that is the Container Terminal Operational System (CTOS) concept that can improve the efficiency level. This is why further research is needed to contribute to facilitate FMEA applications to improve container terminal risk management in situations where uncertainty in high historical failure data and basic probabilistic risk analysis methods can be used using incomplete data. Through this research is known various risks that arise based on the tools at the port, one of them by Ship to Shore (STS) Crane. Based on FMEA calculations it is known that on the hold hatch of the ship crane's wooden bearings when handling by the STS and the protective pin of the spreader hits the ship's hold is the highest risk priority, so it is necessary to get attention as soon as possible.*

Key Words: *Container cranes, FMEA, Green port, Risk analysis.*

1. INTRODUCTION

The management of the port is growing rapidly. At the very least, there are seven developmental trends that will affect port management in the future. Maritime infrastructure, such as very high container terminals, those require economic activity through the transfer of goods and services for both national and international purposes. In practice, systemic techniques have a major impact and security measures that can change over time and with this change process is a timing process, growth or damage to the system can be evaluated and selected [1].

The company in this study is a sizable modern port and uses the only green-technology in Indonesia. The port serves a wide range of services, such as container loading or container services internationally and domestically, installing and unloading reefer containers on international and domestic vessels, international and domestic container shelving, stamp provision and stripping and CFS stuffing.

Research on the risk and management of seaport safety is still rarely discussed in the literature that demonstrated 395 port-related journals published between 1997 and 2008, that continuous risk analysis occupied the role of rear seats in port research encompassed by other aspects involving efficiency analysis, port competition, geographic analysis and spatial evolution, port policy and governance [2, 3]. This research is a research that presents risk management methodology into port container terminal domain. This methodology is a decision support framework that will be used to evaluate port risk to the port or to assess overall risk levels of ports and terminals to facilitate sustainable improvement strategies.

An empirical study was contacted to provide evidence of risk management at a port container terminal in Greece The critical impact on a number of port stakeholders has established a new methodology and the port risk index is a considerable task. The results of the empirical investigations of the two major container terminals in Greece (Piraeus & Thessalonica) provide a workable example through which the reliability of the proposed PRA is indicated and the factors that influence. The main aim of future research is to investigate the effects of other related risks, such as machinery, safety and natural risk, to overall port risk.

Alyami [4] in the research proposed a new method to facilitate the implementation of Failure Mode and Effect Analysis (FMEA) in assessing Safety Performance CTOS. This new approach was developed through the incorporation of the Fuzzy Rule-Based Bayesian Network (FRBN) with Evidential Reasoning (ER) in a complementary way. This prior study provides a realistic and flexible method of describing the input failure information for the estimated risk of individual hazard events (HES) at the lower level of the risk analysis hierarchy. This subsequently is used to aggregate collective safety estimates of HEs, enabling dynamic risk-based decision support in CTOS from a systematic perspective. More importantly, new sensitivity analysis methods are developed and undertaken to rank HEs with respect to their specific risk estimation/risk estimation (local) and risk influence (RI) for this port security system (global). From those researches, risk studies that take the topic of the port to date are still quite rare.

The theme of this research is in accordance with one of the master plan of university research that is the field of good governance. So with the completion of this study is expected to contribute to the dimensions of research and development of the availability of concepts, theories, and the paradigm of knowledge about risk analysis with graphical modeling and mathematical analysis results that can be used widely both on regional, national, and global scope to achieve wealth economic, operational efficiency, and personnel safety at appropriate ports. As for several identification problems in the company that includes there are many risks of occupational accidents, the absence of priority risks, and there is no action plan to prevent the risk that container port transport. The benefits that can be obtained from the implementation of this study are as follows. As a method of learning in conducting research on risk-taking decision-making, appropriate strategies can be applied to minimize hazardous event risk on port container transportation for related institutions, as well as achieving economic wealth, operational efficiency, and personnel safety with risk handling at appropriate ports.

2. MATERIALS AND METHODS

The research method is the stage that must be established before starting to work on solving the problem to be studied. The results of the study were never intended as a direct problem solving for the problems encountered, as research is a part of larger problem-solving efforts. In this section will be explained related to the stages to be conducted in research so that the objectives of the study can be achieved.

The data collected is the data that is required in the research either through surveys, interviews or historical data in the study. As for the data collection stage, there are data collected that is the value of hazardous event and the number of container in the company.

At the stage of data processing done by risk analysis using Failure Mode and Effect of Analysis (FMEA) [5, 6, 7]. Risk analysis has been widely used in some areas. The many application areas are consumer product safety, medical care strategy, facility placement, transport routing (railroad, pipeline, truck), nuclear power and more, risk analysis does not appear as a single calculation, but emerge as support for arguments. On the one hand or another (or both) of strong public debates about actions, regulations, laws and policies. In such cases, the effectiveness of risk analysis relies heavily on what is normally discussed. In verification and validation, the analysis can be fully verified and validated in purely analytical terms, but remains ineffective because it is not accepted and trusted in public debates to be supported. In particular, if one side of the debate can be trusted doubt the risk analysis, its role can be very limited.

Risk management is the implementation of policies, procedures and management practices systematically on the task of building context, identification, analysis, assessment, care, monitoring and communication, is a recurring process that, with each cycle, can contribute progressively to organizational improvement by providing insight management greater risk and impact. Risk management should be applied to all levels, both in strategic and operational context, to specific projects, decisions and risk areas. Risk is the possibility of something happening that will impact the goal. Therefore, it is important to understand the purpose, work unit, project or position before trying to analyze the risks. Risk analysis is often best done in groups with each group member having a good understanding of the objectives under consideration.

Risk assessment is done at the design stage and at several year intervals can be updated for the current conditions. The study details and quantification rates depend on the research objectives and complexity of the situation. Over time, security demand to reduce the likelihood of death or loss of serious detention in Indonesia an industrial operation increased to almost zero. Regardless of public pressure, the company realizes that the cost of accidents is high, more emphasis on foresight and proactive actions. This may arise from the record of safety of big companies that continue to increase even in the best performing companies that can be prevented by accident may still occur. As a result of this overall trend, in recent years in industry interest has been developed in the assessment of operational risk.

The potential hazards identified in the hazard identification stage will be a risk assessment to determine the risk rating of the hazard. Risk assessment is carried out by reference to the Australian Standard / New Zealand Standard for Risk Management (AS / NZS 4360: 2004,) scale. There are 2 parameters used in risk assessment, namely probability and severity. The scale of risk assessment and its description used can be seen in Table 1 and 2. While the example of risk matrix can be seen in Figure 1.

Table -1: Scale "probability" on AS / NZS standard

Level	Description	Information
5	Almost Certain	May occur any time
4	Likely	Often occur
3	Possible	Can happen once in a while
2	Unlikely	Rarely happening
1	Rare	Almost never, very rarely

Table -2: Scale of "severity" on the AS / NZS standard

Level	Description	Information
1	Insignificant	No injuries, little financial loss
2	Minor	Mild injury, little financial loss
3	Moderate	Moderate injury, need medical treatment
4	Major	Severe injury> 1 person, big loss, production disruption
5	Catastrophic	Fatal> 1 person, huge losses and huge impact, cessation of all activities

Likelihood					
5	Medium	High	High	Extreme	Extreme
4	Medium	Medium	High	High	Extreme
3	Low	Medium	Medium	High	High
2	Low	Low	Medium	Medium	High
1	Low	Low	Low	Medium	Medium
	1	2	3	4	5
	Consequence				

Fig -1: Risk matrix

3. RESULTS AND DISCUSSION

The following stage describes the results of this study, which consists of the stage of determining the organizational context, risk identification, risk analysis and evaluation, and action planning on risk. The company serves as a port that serves domestic containers, international containers and dry bulk with food standards. The terminal capacity reaches 342,000 domestic container TEUs and 435,000 TEUs of international containers. Meanwhile, dry bulk capacity is 2000 ton/hour. This terminal is regarded as the most sophisticated terminal in Indonesia and first use the automatic operating system and apply the concept of green port. In line with the increasing interest of service users using loading/unloading services to make the company continue to equip the environmentally friendly terminal with new international facilities and equipment such as Ship To Shore (STS) Crane used in loading and unloading activities at the container port (Figure 2). STS Crane International specification has a boom of 30-40 meters so it can be used to serve Panamax type ships and able to lift loads up to 60 tons with twin lift system (able to lift containers 2 x 20 feet simultaneously).

Fig -2: Ship to Shore (STS) Cranes

3.1 Risk Identification Stage

Table 3 shows the identification of risks in the STS port container transportation area.

Table -3: Risk identification STS port container

No	Risks Identification
1	STS cable dislocation
2	The key of a crooked CTT buffer is hit by a twist lock when it receives unloading from the STS
3	Containers dismantled by STS crash into containers on land
4	2x20 feet container hanging when lifted STS from ship
5	Twist lock spreader STS contact with container roof
6	STS grazed the gangway staircase
7	Water ballast leaking due to d-ring lashing flaked
8	Ladder of truckloads damaged by webbing distress
9	Tent pillars in the lorry trucks were damaged by strayed STS spreaders
10	STS gearbox oil leaks
11	STS gearbox oil hoist is open and causes oil spills in the 250 L dock area causing STS not to operate
12	STS cable ripped due to the process of moving the pipe chart and snagged on the STS power cable causing sparks and STS lights off
13	The protective pin of the spreader hits the ship's hold
14	The operator forgot to change the twin lift mode to 1x40 when unloading the container
15	STS operators do not use twin lift method when lifting container 2x20 "
16	The sideward manhole gate is jammed by the container as it is loaded by the STS
17	STS regarding walkway crane ship
18	Handrail broken when handling hatch bay
19	Container door hinge struck by other containers
20	CTT button stop button cover damaged by hard landing container by STS
21	Crooked railings are hung on hatch when handled by STS
22	Palka hit the wooden cranes of ship crane during handling by STS
23	STS runs over aids when it comes to unloading containers
24	Hatch container roof exposed twist lock STS
25	Stop button CTT hit twist lock plate
26	STS spreader hit the container
27	Safety rail hit the hold
28	Reefer cable broke off while handling with STS
29	Shredded loads are caught in aids
30	The CRT front chassis lock on the left side is twisted by a twist lock container
31	Railing hit by hold
32	Cross deck hit by hold

3.2 Risk Assessment Stage

The risk that has been identified is then analyzed and evaluated using failure mode and effect analysis (FMEA) and then the identified risks are calculated risk priority using RPN (Risk Priority Number). Risk assessment is done by RPN method (risk priority number). RPN is obtained by distributing questionnaires to related companies who understand and understand the risk areas of the container port company. The form of questionnaire for risk assessment by RPN method with the element of assessment consists of Severity (S), Occurrence (O) and Detection (D) is showing the following explanation.

- Severity (S) is a rating of the seriousness of the consequences of failure.
- Occurrence (O) is the frequency or frequency of occurrence of risk. Rating occurrence as in Table 4.
- Detection (D) is the quantification of the control or procedure that exists to regulate the function or that makes the failure detectable. The more and more complete the control then the detection of risk will be easier and therefore the rating will be smaller. Example detection rating table can be seen in Table 5.

Table -4: Occurrence rating

Event	Verbal criteria	Probability in a year	Rank
Almost never	Risk almost never happens	0,00000067	1
Rarely happening	Risk is rare	0,0000067	2
The least	The risk is very little	0,000067	3
A little	The risks are small	0,0005	4
Low	Risks that occur at low levels	0,0025	5
Medium	Risks that occur at the medium level	0,0125	6
A bit high	The risk is rather high	0,05	7
High	The risks are high	0,125	8
Very high	The risk is very high	0,33	9
Almost always	Risk always happens	0,50	10

Table -5: Detection rating

Detection	Possible Detection By Control	Rank
Almost never	Checking hardly detects failure	10
Rarely happening	Very unlikely to check can detect failure	9
The least	Small possibility for checking can detect failure	8
A little	Checks have a low chance of detecting failures	7
Low	Checking the possibility of detecting a failure	6
Medium	Checking the possibility of detecting a failure	5
A bit high	A reasonably large probability check will detect a failure	4
High	Checking will most likely detect failure	3
Very high	Checking almost certainly can detect failure	2
Almost always	Checking can certainly detect failure	1

Based on the result of risk assessment using FMEA, as the next stage of risk analysis and evaluation, the RPN value is ranked to know the priority of risk. The higher the RPN value, the higher the priority of handling the risk. The following in Table 6 is a sequence of risk priorities based on the RPN value from the highest to the lowest that results in a priority order to be addressed.

Table -6: FMEA calculation

No	Risk identification	S	O	D	RPN
1	STS cable dislocation	4	7	3	30
2	The key of a crooked CTT buffer is hit by a twist lock when it receives unloading from the STS	3	7	4	30
3	Containers dismantled by STS crash into containers on land	4	6	3	54
4	2x20 feet container hanging when lifted STS from ship	4	4	4	18
5	Twist lock spreader STS contact with container roof	3	7	3	21
6	STS grazed the gangway staircase	3	7	3	36
7	Water ballast leaking due to d-ring lashing flaked	5	3	4	45
8	Ladder of truckloads damaged by webbing distress	5	4	3	32
9	Tent pillars in the lorry trucks were damaged by strayed STS spreaders	6	3	3	45
10	STS gearbox oil leaks	6	3	3	24
11	STS gearbox oil hoist is open and causes oil spills in the 250 L dock area causing STS not to operate	3	6	3	10
12	STS cable ripped due to the process of moving the	3	6	3	27

No	Risk identification	S	O	D	RPN
	pipe chart and snagged on the STS power cable causing sparks and STS lights off				
13	The protective pin of the spreader hits the ship's hold	3	6	3	84
14	The operator forgot to change the twin lift mode to 1x40 when unloading the container	2	6	4	60
15	STS operators do not use twin lift method when lifting container 2x20 "	4	6	2	64
16	The sideward manhole gate is jammed by the container as it is loaded by the STS	5	3	3	36
17	STS regarding walkway crane ship	5	3	3	54
18	Handrail broken when handling hatch bay	7	2	3	42
19	Container door hinge struck by other containers	3	6	2	63
20	CTT button stop button cover damaged by hard landing container by STS	3	6	2	20
21	Crooked railings are hung on hatch when handled by STS	6	3	2	48
22	Palka hit the wooden cranes of ship crane during handling by STS	4	4	2	84
23	STS runs over aids when it comes to unloading containers	5	3	2	60
24	Hatch container roof exposed twist lock STS	2	5	3	18
25	Stop button CTT hit twist lock plate	9	1	3	54
26	STS spreader hit the container	6	2	2	48
27	Safety rail hit the hold	3	7	1	63
28	Reefer cable broke off while handling with STS	2	5	2	14
29	Shredded loads are caught in aids	3	6	1	36
30	The CRT front chassis lock on the left side is twisted by a twist lock container	6	1	3	54
31	Railing hit by hold	7	2	1	54
32	Cross deck hit by hold	10	1	1	72

4. CONCLUSION

The conclusion of this research is through the process of collecting data on the STS port container transport area obtained 32 types of risk that occurred. From these risks, there are 32 priority of accident risk and occupational safety at STS port container transportation area based on RPN of risk analysis and evaluation. The highest risk priority is on the hold hatch the ship crane's wooden bearings when handling by the STS and the protective pin of the spreader hits the ship's hold. The lowest risk priority is the open STS gearbox oil hoist and cause oil spills in the 250 L dock area causing STS not to operate.

In the final stages of risk analysis, a risk action plan is prepared by brainstorming and discussion by considering the risk analysis and evaluation as well as the company's capabilities. Action planning against risk on the first priority of the hatch hit the ship crane wooden bearings when handling by STS by counseling with the STS operator. In addition, the improvement and development of STS operator skills is also required by conducting STS-related training or training. The next risk action plan that protects the spreader pin hits the ship by conducting a safety checklist and if found non standard conditions will be made note of protest to the master of the vessel as well as by re-emphasizing the supervisory function in the field to direct the STS operator according to work instruction (IK) Lashing / Unlashing and IK Vessel Foreman.

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