BACHELOR THESIS – ME 184841

DETERMINATION OF MAINTENANCE TASK AND SCHEDULED ON SHIP TO SHORE CRANE USING RELIABILITY CENTERED MAINTENANCE METHOD

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Double Degree Program
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TUGAS AKHIR – ME 184841

PENENTUAN TUGAS PEMELIHARAAN DAN PENJADWALAN PADA SHIP TO SHORE CRANE MENGGUNAKAN METODE RELIABILITY CENTERED MAINTENANCE

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Surabaya
2020

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APPROVAL FORM

DETERMINATION OF MAINTENANCE TASK AND SCHEDULED ON SHIP TO SHORE CRANE USING RELIABILITY CENTERED MAINTENANCE METHOD

BACHELOR THESIS

Submitted to fulfill one of the requirements to obtain
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on

Digital Marine Operational and Maintenance (DMOM)
Bachelor Program Department of Marine Engineering
Faculty of Marine Technology
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July, 24th 2020

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AGUSTUS, 2020

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6. Dr. Ing Wofgang Busse

NO	NRP	NAMA	JUDUL	HASIL P3	REVISI
1	4211641000040	MUHAMMAD NOVAL FAHMY	IMPLEMENTATION OF MAINTENANCE METHOD ON STEAM TURBINE USING RELIABILITY CENTERED MAINTENANCE (RCM)	Lulus dengan catatan A	1. Pastikan seluruh aktivitas dapat menyelesaikan masalah/problem 2. Tuliskan kriteria pada laporan/analisis untuk menjawab LTA 3. Langkah-langkah FMEA menjawab 7 pertanyaan basic RCM II cantumkan pada laporan
2	4211640000022	ENGGAR DYWARI SUMINTA	IMPLEMENTASI METODE RELIABILITY CENTERED MAINTENANCE (RCM) II PADA CLOSE COOLING WATER SYSTEM PEMBANGKIT LISTRIK TENAGA UAP	Lulus dengan catatan AB	1. Crosscheck failure mode dan effect dengan engineer/teknisi di PLTU Paiton 2. Berikan komentar pada task selection task, jelaskan hasil masing-masing prosentase pada laporan 3. Rekomendasi dari vendor di re-analisis
3	4211641000041	ALMAS BRILLIANO	DETERMINATION OF MAINTENANCE TASK AND SCHEDULE ON SHIP TO SHORE CRANE USING RELIABILITY CENTERED MAINTENANCE METHOD	Lulus dengan catatan AB	1. Crosscheck failure mode dan effect dengan engineer/teknisi 2. Berikan komentar pada task selection task, jelaskan hasil masing-masing prosentase pada laporan.
4	4211640000074	AVECENNA AMARULLAH VERSAPUTRA	PENENTUAN STRATEGI PERAWATAN PADA PERALATAN CSU-2 MENGGUNAKAN METODE RELIABILITY CENTERED MAINTENANCE (RCM) II	Lulus dengan catatan AB	1. Data cost pada awal-awal (latar belakang), silahkan dicrosscheck Kembali. 2. FMEA spreadsheet narasi function, failure mode, effect diperbaiki kembali. 3. Berikan ulasan perbandingan hasil RCM dengan maintenance action existing

DECLARATION OF HONOR

I hereby who signed below declare that:
This bachelor thesis has written and developed indenpendently without any plagiarism act, and confirm consciously that all data, concepts, design, references, and material in this report own by Digital Marine Operation and Maintenance (DMOM) in Department Marine Engineering ITS and the external sources are indicated such as cited sources, literatures and other professional sources.

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If there is plagiarism act in the future, I will responsible and receive the penalty given by ITS according to the regulation applied.

Surabaya, July 2020

Almas Brilliano

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ABSTRACT

Ship to Shore (STS) crane or commonly referred to as Container Crane (CC) is a loading and unloading equipment that is very important to move containers from the ship to the port and vice versa. Therefore, increasing the efficiency of maintenance activities during operations is an important action that must be taken by the company.. The results of this research obtained by monthly maintenance report from one of the stevedoring companies that occurred in 2018 until 2019.

Reliability Centered Maintenance (RCM) is a structured way to determine maintenance strategies based on input/expert/actual data in the field with the output of method optimization and maintenance schedules for each particular asset by analyzing the failure.

The implementation of RCM method on the STS Crane maintenance using qualitative analysis. The expected result is to produce a maintenance task and schedule without offending maintenance costs, and these will be summarized into maintenance task in the form of work package. Determination of the level of critical consequences of each component on the crane can be done using the Logic Tree Analysis. Based on the results of this final project, there are 27 failure modes obtained based on the analysis of functions and functional failure of 11 main components in the crane. The percentage of maintenance task is 44% for scheduled condition tasks, 44% for scheduled discard tasks, and 11% for failure finding task.

Keywords: Ship To Shore Crane, Reliability Centered Maitenance, FMEA

PENENTUAN TUGAS PEMELIHARAAN DAN PENJADWALAN PADA SHIP TO SHORE CRANE MENGGUNAKAN METODE RELIABILITY CENTERED MAINTENANCE

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ABSTRAK

Ship to Shore (STS) *crane* atau biasa disebut sebagai derek peti kemas, adalah peralatan bongkar muat yang sangat penting untuk memindahkan kontainer dari kapal ke pelabuhan dan begitu juga sebaliknya. Oleh karena itu, meningkatkan efisiensi kegiatan pemeliharaan selama operasi merupakan tindakan penting yang harus diambil oleh perusahaan. Hasil kajian ini diperoleh dengan laporan pemeliharaan bulanan dari salah satu perusahaan bongkar muat yang terjadi pada 2018 sampai dengan 2019.

Reliability Centered Maintenance (RCM) adalah cara yang terstruktur untuk menentukan strategi pemeliharaan berdasarkan data input/expert/aktual di lapangan dengan hasil optimisasi metode dan jadwal pemeliharaan untuk setiap asset tertentu dengan menganalisa kegagalan.

Implementasi metode RCM pada perawatan STS crane dengan menggunakan analisis kualitatif hasil yang diharapkan adalah untuk menghasilkan tugas pemeliharaan dan jadwal tanpa menyinggung biaya pemeliharaan, serta akan dirangkum menjadi tugas pemeliharaan dalam bentuk paket pekerjaan. Penentuan tingkat konsekuensi kritis dari setiap komponen pada derek dapat dilakukan dengan menggunakan *Logic Tree Analysis*. Berdasarkan hasil dari tugas akhir ini, terdapat 27 mode kegagalan yang diperoleh berdasarkan analisis fungsi dan kegagalan fungsional dari 11 komponen utama dalam derek. Persentase tugas pemeliharaan adalah 44% untuk scheduled on condition task, 44% untuk scheduled discard task, dan 11% untuk failure finding task.

Kata Kunci: Ship To Shore Crane, Reliability Centered Maitenance, FMEA

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PREFACE

The author would like praise be to Allah SWT for His grace, author can finish this bachelor thesis titled "Determination Of Maintenance Task And Scheduled On Ship To Shore Crane Using Reliability Centered Maintenance Method" to fulfill the requirement to achive Bachelor Engineering in Marine Engineering Department, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopemeber.

The author realizes that there are factors that become obstacles in the writing process. And success in this settlement is also inseparable from the support and assistance from various parties. For this reason, the author wishes to express his gratitude to:

1. Author's beloved parents, Mr. Bondan Brillianto, S.T., M.M. and Mrs. Arumy Budhi Handayani, A.Md.
2. Author's brother, Akmal Hady Hutama.
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4. Ir. Hari Prastowo, M.Sc. as Head of Digital Marine Operation and Maintenance (DMOM) Laboratory.
5. Ir. Dwi Priyanta, M.SE. as author's first supervisor for this research.
6. Nurhadi Siswantoro, S.T., M.T. as author's second supervisor for this research.
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9. Madina Nur Pratiwi, S.T., B.Eng. and Rafli Mahadika Ariapratama, S.T., B.Eng. as author's friends who support for this research and helped in understanding of Reliability Centered Maintenance.
10. Mr. Nurul as a company supervisor for this research.
11. All Marine Engineering students batch 2016 (Voyage16) and all member of Digital Marine Operation and Maintenance (DMOM) Laboratory who always give support to the author for four years of college.

The author realizes that this bachelor thesis remains far away from perfect, and would like to apologize for the shortcomings contained in this bachelor thesis. The author also hope this paper as an addition to insights in understanding the methods of proper maintenance, especially those in the maritime field to support the performance of activities of loading and unloading.

Surabaya, 24th July 2020

Author

CHAPTER I
INTRODUCTION

1.1 Background

The selection of Ship To Shore (STS) Crane as a container carrying equipment at PT. Terminal Teluk Lamong is based on supports the revitalization of APBS (Alur Pelayaran Barat Surabaya). One thing that underlies the selection of topics is the opportunity of the entry of commercial ships 80 thousand DWT become larger, as well as Logistic Performance Index (LPI) placing Indonesia at the rank of 53 in 2013-2014. Thus, the terminal develops innovations that use the concept of Green Port that can reduce the use of fuel oil (BBM) and the efficiency of electrical power can be suppressed 50%. STS crane also can transport up to 2 containers measuring 20 feet at once and use a power of 1.2 megawatt.

In operations performed 24 hours a day, there is some damage that causes shutdown and repairs are carried out within a certain time. The equipment is quite influential in the operation of STS Crane, among others, spreaders, hoist motors, motor trolleys, wire ropes.

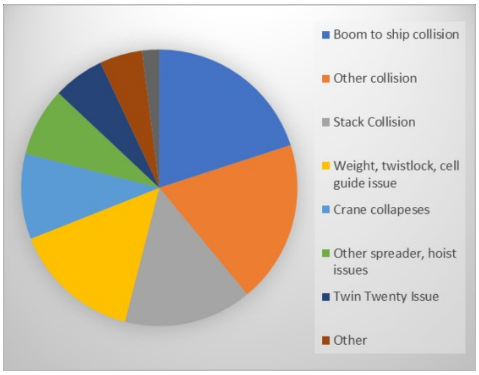

Figure 1.1 Percentage trend cause accident in the STS Crane globally (2014-2018)

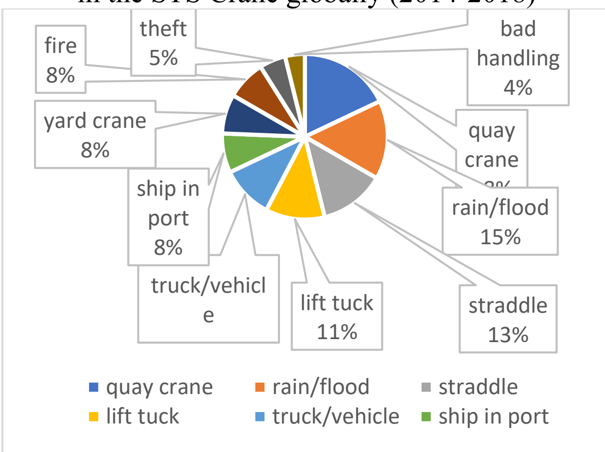

Figure 1.2 Percentage issue in container terminals globally (2014-2018)

Based from the statistical data analysed by the TT Club, Figure 1.1 shows that the percentage trouble causes due to structural damage from spreader, hoist issue, twistlock, cell guide issue was 23% of total incidence. Figure 1.2 shows that the percentage of accidents due to Quay Crane or STS Crane reaches 18% of the total number of accidents in terminals per year[1].

In the loading and unloading activities, requires adequate and fast container carrying equipment in operation. The process of activities will take a long time if the damage to STS Crane is not immediately handled. Some of the dangers that will be experienced by loading and unloading companies due to crane damage are:

a. Slowing delivery of goods
b. Vessel queues occur and the addition of vessel waiting time at the dock causes additional docking charges
c. Stacking containers in terminals and on board

The company as well as PT. Terminal Teluk Lamong have implemented a treatment method that is quite routine implemented. But the treatment program that has been applied is not maximized because there are activities that should not be done and also still occur minor damage, so with this method is expected to implement effective and beneficial treatment methods.

1.2 Problem Statement

The problem formulation in this research is to answer the question of:

1. How to analyse the failure and reduce down time caused by component in the STS crane using FMEA (Failure Mode Effect Analysis) method?
2. How to determine the appropriate solution in maintenance task against STS Crane in order to increase the reliability value of the equipment to reduce the downtime?
3. How to recommend for STS Crane maintenance in the company?

1.3 Scope and Limitation

The scope and limitation on the problem in this thesis is:

1. This research object is STS 01 International Crane owned by PT. Terminal Teluk Lamong.
2. The failure data used is monthly report maintenance equipment on the STS crane, period of December 2018 – November 2019.
3. This thesis using guide for survey based on Reliability Centered Maintenance II method.

1.4 Objectives

The purpose of this research is:

1. Identify the failure and break down time caused by component in the STS 01 International crane using FMEA (Failure Mode Effect Analysis) method.

[1] TT Club, Jones, Laurence. November 2015. Quay Crane Safety Issues. https://www.ttclub.com/news-events/articles/quay-crane-safety-issues-134071/

2. Determine the appropriate solution in maintenance task against STS Crane in order to increase the reliability value of the equipment to for the effectiveness of maintenance activities.
3. Provide the right recommendation treatment for STS Crane in the company.

1.5 Benefits

The expected benefits of this thesis are as follows:

1. As a means to evaluate and improve the maintenance system on the crane system that has been done
2. Provide advice that can be recommended to the maintenance of the company in performing proper maintenance on the operating system in the STS crane
3. Can help new workers who lack the experience or ability to perform maintenance activities based on information from the RCM worksheet and workpackage.

1.6 Deliverable Research

The output of this research is the maintenance task based on information from the RCM info worksheet, the decision worksheet, and scheduling for STS Crane.

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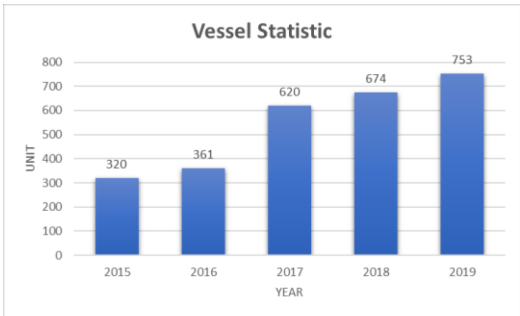
CHAPTER II
LITERATURE REVIEW

2.1 Problem Overview

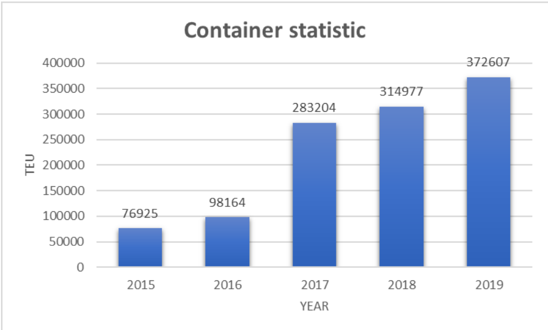
PT. Terminal Teluk Lamong is a special port of commercial vessel located on the border of Surabaya and Gresik with the focus of loading and unloading activities. This port has several stevedoring tools that support the work of loading and unloading, including Ship To Shore Crane (STS Crane), Automated Stacking Crane (ASC) and Rubber Tyred Gantry (RTG Crane). Currently, PT. Terminal Teluk Lamong has 10 STS, 5 STS for International docks and 5 STS domestic docks.

Figure 2.1 Vessel Statistic Berthing Data at Terminal Teluk Lamong 2015-2019



(source: teluklamong.co.id/en/vessel-statistic)

Figure 2.2 Loading Unloading Container Activities Statistic Data at Terminal Teluk Lamong 2015-2019



(source: teluklamong.co.id/en/container-statistic)

Figure 2.1 and 2.2 show the projection of loading and unloading activities in the 5-year period from 2015 to 2019 increased, and the increase in the year 2017 is significant due to the start of optimized operational 10 STS Crane. In the monthly report in 2018-2019 also reported the several factors that caused the commission days target were due, which include:

Table 2.1 Accident Report 2018-2019

Accident Report			
Unit	day date	Down Time (hours)	Description
STS 02-I	29-Apr-19	10.17	Lifting Container Abnormal, Twistlock & Bolt Blocking Pin Telescopic Broken
STS 05-I	8-Feb-19	82.5	Wire Rope Broken when Handling Container
STS 04-I	28-Jan-19	74.5	
STS 02-I	27-Jul-19	4.5	Pull Up Container Double Twin Abnormal
STS 05-D	5-May-19	0.67	Radar ship right side bump flores sea ship
STS 04-I	10-July-19	0.83	Wire rope no. 3 stuck in wolkway girder
STS 05-I	17-Oct-19	3.33	Eccentric Overload

(source: Monthly Report Maintenance of STS Crane)

Based on monthly report maintenance STS Crane operator, there are several causes that make the equipment always damaged even though it has been prevented by preventive maintenance:

- Operational time of crane reaching 23 until 24 hours

The Crane is operated continuously for 23 hours to 24 hours each day, causing some components to be over heated and its strength decreases.

- Improper operation

In operation there is an error from the operator who is less careful and thorough[2].

To reduce the risk of damage to the loading device, the implementation of maintenance conducted by PT. Teluk Lamong Terminal is to do preventive maintenance by applying routine maintenance scheduling based on running hour and predictive maintenance based on the condition of the tool.

[2] Monthly Report Maintenance STS Crane, 2018-2019

2.2 Ship To Shore Crane

Figure 2.3 Ship To Shore Container Konecranes

Ship to Shore (STS) or commonly referred to as Container Crane is a tool used to unpack or load containers from and to the jetty to the ship (vice versa) and the placement of this container payload is on the side of the terminal. STS crane productivity has invariably been one in every of the critical assets of terminal productivity. However the crane is merely one in every of the terminal parts that controls production. The aim of reliability analyses is to provide a decision-making tool for uncertainty considerations in structural design and management[3]. Increasing productivity is based on BCH (Box Crane Hour). The determination of the loading and unloading operation depends on[5]:

- Operating parameters;
- Container yard performances;
- Vessel and crane parameters

In crane system, divided into 3 essential types of components[4]:

Table 2.2 STS Crane Component

STS Crane Component		
Electrical System	1	Current supply, motor blower, breaker
	2	Alarm SystemDrive control, micro verter, voltage control
	3	Panel hoist, trolley, slewing, cabin
Safety System	Brake system, Switch limit like: Hoist, Trolley, Slewing, Over Load Limit, Fuse, Stopper	
Drive System	Slewing	Motor Slewing, ring gear, gear box, reducer, puley-puley, v belt/coupel
	Trolley	Motor trolly, wire rope, puley, gear box
	Hoisting	Motor hoist, spreader. gear box, drum/ wire rope, hook, grease system

[3] Bucas, Simon. 2005. *Stress-strength interference method applied for the fatigue design of tower cranes*

[4] Departemen Pekerjaan Umum. 2007. *Perbaikan Komponen Tower Crane, Baik Di Lapangan Maupun Di Workshop*

The common problem from the STS crane is from the degradation of the wire rope, crane skew, wear of end truck wheels, problem from electrification system and damaged from the spreader and twistlock.

For this type of crane, still using conventional system or manually operated cranes, the performances mainly depend on a humanf factor, example from capabilities of operator on the field. The power supply of electrical using Alternating Current (AC), where use of AC hoist motors have dedicated inverters and each motor is controlled separately. QC equipped with an AC must be continuously hooked up to an AC power supply or generator.

2.3 Maintenance

Maintenance is the actions necessary undertaken for physical assets, to will be repaired or returned under certain conditions in the specific period, with all combination of managerial actions and technical. With maintenance activities, it is hoped that the asset does not suffer a reduction of reliability and availability. The maintenance activities divide into three categories, preventive maintenance and corrective maintenance[5]:

a. Corrective Maintenance: The repair or unscheduled maintenance to return items or assets to a given state, performed as a result of maintenance personnel or others perceived deficiencies or failures.

b. Preventive Maintenance: Maintenance and service by maintenance department to keep up facilities in satisfactory operational conditions by performing systematic inspection, detection and correction of the latest failures, whether or not before development becomes a significant failure or before the prevalence.

c. Breakdown / Reactive Maintenance: A maintenance strategy is performed once the appliance experiences failures or approaches that area unit performed after they don't seem to be in operation considerably. This strategy is extremely straightforward, but however it may be high risk of failure.

d. Predictive Maintenance : The strategy of maintenance that implements predictive system failure equipment may occur based on conditions monitoring. The purpose is to kept a minimum cost and downtime, also improved the reliability. The aim of the maintenance is:
   - To avoid production failure
   - To minimize the risks of casualties
   - To improve occupational safety
   - To secure production responsibility
   - To accomplish the required time

[5] B.S. Dhillon (2006). Maintainability, Maintenance, and Reliability for Engineers.

2.4 Total Productive Maintenance

TPM is a maintenance system as an increase in the quality of production through maintenance to ensure all equipment and work equipment such as machinery, equipment and work tools are in good condition and minimize damage that can impact the delay in the production process. TPM is also to prevent six failures: Breakdown, Setup and Adjustments, Small Stops, Slow Running Startup Defect, and Production Defect[6]. Measurement tool used by TPM is using Overall Equipment Effectiveness, with the formula as follows:

$$OEE = Availability \times Performance\ Rate \times Quality$$

2.5 Condition Based Monitoring

CBM is a decission making strategy where the decision to perform maintenance is reached by observing the condition of the system and/or its components.[7] There are several benefits using CBM is gives prior warning of impending failure and increased precision in failure prediction. But disadvantages from CBM is it has some limitation in ensuring the accuracy of diagnostics and prognostics, the investment cost for install and use monitoring equipment and to develop some level of modeling or decision making strategy CBM, and also for training on staff is usually high.[8]

Table 2.3 Comparison between the two maintenance methods, TPM and CBM

	TPM	**CBM**
Advantages	reduce the occurrence of emergency breakdowns	gives prior warning of impending failure
	system for continuously maintaining and controlling equipment	increased precision in failure prediction
	reduced absenteeism and enhanced communication in the workplace	
Challenges	Inadaquate knowledge	limitation in ensuring the accuracy of diagnostics and prognostics
	lack of leadership and management support	investment cost for install and use monitoring equipment
	Inadaquate workshops and trainings	cost for training on staff is usually high
	excess inventory	
	organizational culture	

[6] D.R. Kiran (2016): Total Quality Management: Key Concepts and Case Studies

[7] Kothamasu R, Huang SH, Verduin WH (2006): System health monitoring and prognostics-a review of current paradigms and practices

[8] Jong-Ho Shina, Hong-Bae Jun (2015) On condition based maintenance policy

2.6 Reliability Centered Maintenance (RCM)

2.6.1 Definition

Reliability Centered Maintenance is to determine PM requirements and optimize maintenance system for a physical asset in its operating environment. RCM is also a structured way to determine the treatment strategy based on the data input/expert/actual data in the field with the output of optimization of maintenance on equipment/Functional Location specified. Structuring, the process of logic to develop or optimization of maintenance. Another way to look at RCM is to analyse damage to determine the treatment methods and schedule unique treatments for each asset. The main purpose of RCM is to reduce maintenance costs, by focusing on the most important functions of the system, and avoiding or removing maintenance measures that are not fully required [9]**.** Work process of the RCM Method is:

1. Preparing the analysis data
2. Determining the asset to be analyzed
3. Identifying the function of the asset
4. Identifying the failure from each component asset
5. Identifying the possible causes from each component asset
6. Identifying the effects of each failure function
7. Determining the maintenance task

Output from the RCM Method is:

a) Proactive maintenance: schedule restoration task, schedule discard task and on-condition task
b) Default task: redesign, failure finding task, no schedule maintenance

2.6.2 Success Story of RCM

The history of RCM method implementation has undergone a change of up to 3 generations, in the first generation is still focusing on improvement when the condition is damaged, then in the second generation began to have maintenance and control scheduling work but with low-end computer technology. Then in the third generation began with the technique of treatment of failure analysis and its impacts, condition monitoring, upgrading computer technology, multiskilling and good teamwork.

- 1965-1967, RCM was implemented in the aviation industry on Boeing 747 where the implementation resulted in satisfactory results.
- 1978, RCM was first applied to vessels in the U.S. Navy-USS Roark.
- In the following year, RCM became the dominant method applied to U.S. Navy ships.
- 1984, RCM widened authorized Maintenance System Generator in 3 US nuclear power plants.

[9] Rausand, Marvin. (1998). Reliability Centered Maintenance, Department of Production and Quality Engineering, Nurwegian University Science and Technology

- In the following year, RCM became a method applied to mining and manufacturing companies.
- 1990, RCM applied to French nuclear power plant.
- 1994, RCM applied for transmission and distribution facilities in Bonneville Power Administration[10].
- In the same time, an additional 10-15% in savings of TXU Energy is expected after implementation of RCM method.

2.6.3 The Purpose of RCM

The purpose of the RCM method is used in treatment methods:

1. Higher safety and environmental integrity
2. Performance improvement of operation
3. Maintenance cost effectiveness for the better
4. Life time of the equipment becomes longer
5. Complete Database
6. Greater personal motivation
7. Good teamwork

2.6.4 Component of RCM

Inside the RCM method, there are four important components in it, namely preventive, reactive, proactive, predictive and inspection. This strategic component of maintenance is also applied to the type of other maintenance.

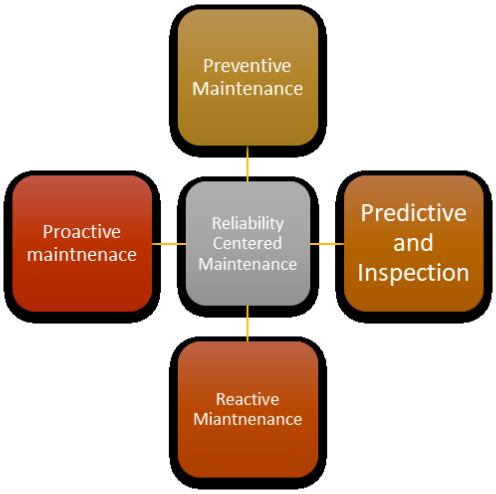


Figure 2.4. Components of RCM

[10] Wilmeth, Randall G., P.E, and Usrey, Michael W., Ph.D., P.E., C.P.I.M. December 2000 Evaluating A Reliability Centered Maintenance Program For Substation Equipment At New Century Energies

2.6.5 Failure Mode Effect Analysis

Failure Mode Effect Analysis (FMEA) FMEA is a qualitative tool analyze, identify and classify the failure mode and failure effect of the every components whose failure in the process will lead to possible and undesirable consequences [11], with the function to give the data for the eliminate point of failures. In implementing the FMEA requires the systematic risk value of each item. The output from the FMEA is:

- Potential failure modes can be ranked by Hidden, Safety, Environment, Occurance from Logic Tree Analysis
- Potential list of process and monitoring systems

The key steps of the analysis process include [12]:

• Identification of causes and contributing factors;
• Description of safeguards in place;
• Identification of actual and potential effects;
• A list of recommendations for managing risks

Table 2.4 Example of FMEA Worksheet Container Speader

<table>
<tr><td colspan="2">System</td><td colspan="2">Facilitator</td><td colspan="2">Date</td><td>Sheet</td></tr>
<tr><td colspan="2">Container Spreader</td><td colspan="2"></td><td colspan="2">12/14/2018</td><td>1</td></tr>
<tr><td colspan="2">Sub-System</td><td colspan="2">Auditor</td><td colspan="2">Date</td><td>of</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2">12/14/2018</td><td>1</td></tr>
<tr><td colspan="2" rowspan="2">FUNCTION</td><td colspan="2">FUNCTIONAL FAILURE</td><td colspan="2">FAILURE MODE</td><td>FAILURE EFFECT</td></tr>
<tr><td colspan="2">(Loss of function)</td><td colspan="2">(Cause of failure)</td><td>(What happens when it falls)</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">To lift the container with the locking mechanism attached to the four corners.</td><td>A</td><td>Broken of twist lock</td><td>1</td><td>Operator's inaccuracy in placing container hole</td><td>Spreader can't lock the container</td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">The cable pin on the spreader panel doesn't detect voltage</td><td>1</td><td>There is no power on proximity sensor</td><td rowspan="2">Can't locked unlocked</td></tr>
<tr><td>2</td><td>Not correspond to the actual wiring position</td></tr>
</table>

2.6.6 Decision Critical Asset and Consequence

In determining the asset and the density, it has been specified with the RCM Worksheet II Decision worksheet which is the second worksheet document in use for the record/register answer of the question that arises from the decision diagram, which includes information reference, consequence evaluation, proactive task & default action, proposed task, initial interval, and can be done by. Before making a decision, must be in the asset register and plant register to find out the critical assets that need to be done for the RCM. Failure of consequence from the asset divide into hidden function, safety, environment, and operation.

[11] Tang, Yang. 2016. *A framework for identification of maintenance significant items inreliability centered maintenance*
[12] Mullai, Arben. 2006. Risk Assessment Frameworks and Techniques

Table 2.5 RCM II Decision Worksheet

System							Systen N2			**Facilitator**				**Date**	Sheet
Sub-System							Sub-System N2			**Auditor**				**Date**	of
Information reference			Consequence Evaluation				**H1 S1 O1**	**H1 S1 O1**	**H1 S1 O1 N3**	Default action			Proposed task	Initial Interval	Can be done by
F	FF	FM	H	S	E	O				H4	H5	S4			

2.6.7 Seven Basic Question of RCM

Seven questions in the RCM method are summarized in the RCM II Decision Worksheet which is categorized as follows[13]:

1. Function.
   a. Primary function: Speed, output, carrying capacity or storage capacities, product quality and *customer service*.
   b. Secondary function:Safety, control, control, comfort, structural integrity, economy, protection, operating efficiency, environmental regulatory compliance, and even asset performance.

2. Functional Failure
   Functional failure from the equipment seen from the failures that have occurred, the risks that will occur, and the impact of preventive maintenance.

3. Failure Modes
   The next stage is identifying the cause of any failure to take preventive measures.

4. Failure effects
   This phase illustrates the impact of each component's failure mode.

5. Failure consequences

[13] Moubray, J. (1991). Reliability Centered Maintenance (RCM II)

Table 2.6 Decision criteria of failure consequence based on RCM II

Failure Consequence	Consequence	Not have consequence
H: Hidden Function	Operating condition is normal: the failure modes can't be known by the operator directly	Operating condition is normal: failure modes can be immediately known to the operator
S: Safety	Operator safety: impacted by failure modes	Operator safety: secured from failure modes
E: Environment	The surrounding environment: affected by failure modes	The surrounding environment: secured from failure modes
O: Operational	Output of the operation: affected by failure modes	Output of the operation: secured from failure modes

6. Pro-active task
   Determination of type of maintenance strategy based on the failure mode of each component. In the prevention there are based on or not based on the condition of the performance of the component, and grouped into three categories namely:

   a) Scheduled on condition: Maintenance activities by conducting measurements when operating to look for signs of damage. This system is viewed from Potential failure and Functional Failure intervals[14].

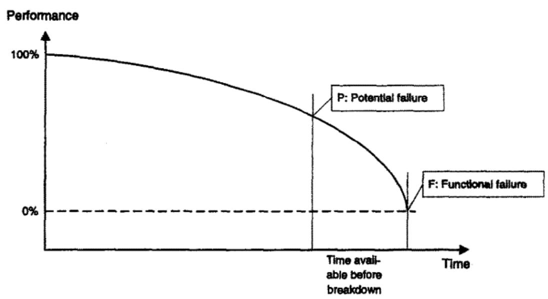


Figure 2.5 P-F interval

   b) Scheduled restoration: Component repair activities on a pre-defined schedule before a certain age limit.
   c) Scheduled discard: Replacement activity on the component reaches a set age.

7. Default task

[14] Rausand M. 1998. Reliability Centred Maintenance

- Failure-finding task: perfrom when proactive task cannot be found which reduces the risk of the multiple failure associated with a hidden function. The formula used in the determination of the failure-finding task is as follows[15]:

$$FFI = 2 \text{ x unavailability x } M_{TIVE}$$

Note:
FFI = Failure Finding Interval
Unaivailability= depends on availability device
M_{TIVE} = depends on Mean Time Between Failure of the device

- Redesign: perform when proactive task cannot be found which reduces the risk of the multiple failure which could affect safety.
- No scheduled maintenance or run to failure: perform when proactive task is not worth doing if over period of time it costs less than cost of operational and repairing. An item will be allowed to operate until failure.

2.7 Logic Tree Analysis

Logic Tree Analysis (LTA) contains information about the number and function failure name, number and mode of damage, critical analysis and additional information needed. There are four things in assessing critical analysis, which is based from factor of hidden, safety, environment, and operation[16]. Four factors are to decide on the proposed task in each question in the failure of the logic tree analysis, and the results that can be scheduled on the condition task, restoration task, discard task, failure finding task, redesign, combination task, or no scheduled maintenance.

2.8 Literature Study

Tabel 2.7 Literature Study

Title	Author(s)	Summary
Research Review on Reliability Centred Maintenance	B.Devaraj Naik and Pradeep Kumar Soni	Describes the importance of reliability centred maintenance introduces a maintenance plan designed for maximum safety in an economical manner and making the system more reliable.
Maintainability, Maintenance, and Reliability for Engineers	B.S. Dhillon	This book provides information Maintability, Maintenance. Reliability terms and definition, RCM, corrective & preventive maintenance defintion and steps.

[15] Moubray, J. (1991). Reliability Centered Maintenance (RCM II)

[16] Pranoto, Jeffrynardo. 2013. *Implementasi Studi Preventive Maintenance Fasilitas Produksi Dengan Metode Reliability Centered Maintenance Pada PT. XYZ*

A framework for reliability and risk centered maintenance	J.T. Selvik, T. Aven	this paper presented and discussed the RRCM framework: a framework based on the existing RCM, which improves the risk and uncertainty assessments by adding some additional features to the existing RCM methodology
An Introduction to Reliability and Maintainability Engineering	Charles E. Ebeiling	This chapter discusses about FTA, downtime analysis and method
Reliability Centered Maintenance	Marvin Rausand	This paper presents a structured approach to RCM, and discusses the various steps in the approach. The RCM method provides a framework for utilizing operating experience in a more systematic way.
Study Reliability Centered Maintenance (RCM) of Rotating Equipment through Predictive Maintenance	Mariam Altaf Tarar	This paper presents XYZ Company case, where maintenance can be properly planned and enables to take maintenance action on basis of decision made with evidence and reduce maintenance staff unnecessary actions.
Automation of Ship-To-Shore Container Cranes: A Review of Stateof-the-Art	Nenad Zrnić, Zoran Petković, Srđan Bošnjak	This paper provides the state-of-the-art of automation of ship-to-shore (STS) container cranes, as the biggest investments in the port terminal system and also shows a short survey of some most important and recent researches in control of ship-to-shore cranes, and main principles of operation of antisway currently existing devices
Quay Cranes in Container Terminals	A. Bartošek*, O. Marek	This paper deals with quay cranes, comparing particular specific crane´s components and analyzed of the optimal quay crane productivity, with regard to contemporary requirements.
RCM- Gateway to World Class Maintenance	Anthony M. Smith, Glenn R. Hinchliffe	examples of actual results from the systems analysis process at the component level. These have been selected to illustrate the type of technical benefits that our clients have realized from their RCM program.
A framework for identification of maintenance significant items inreliability centered maintenance	Yang Tang a, *, Qingyou Liu a, b, Jiajia Jing c, Yan Yang d, Zhengwei Zou	This paper provides a quantitative analysis by establishing evaluation indexes and scoring standard of the MSI based on theAnalytic Hierarchy Process (AHP) on case study drilling pump.
CBM, TPM, RCM, and A-RCM – A Qualitative Comparison of Maintenance Management Strategies	Deepak Prabhakar P, Jagathy Raj V. P	This paper provides the salient features of CBM, TPM, RCM and A-RCM and presents a qualitative comparison of these strategies so as to provide implementers, primarily from the process industry.
An overview of time-based and condition-based maintenance in industrial application	Rosmaini Ahmad 1, Shahrul Kamaruddin	This paper presents an overview of two maintenance techniques widely discussed in the literature: timebased maintenance (TBM) and condition-based maintenance (CBM).

Risk Analysis At Ship To Shore (STS) Cranes in Container Terminal Operational System Of A Greenport Using Failure Mode And Effect Analysis	Debrina Puspita Andriani	This paper is a research that presents risk management methodology into port container terminal domain.
Crane accidents and their prevention revisited development	Kari Hgkkinen	The aim of the paper was mainly on the basis of accident records to draw conclusions for further developments in technical measures to prevent crane accidents and to identify priority areas of further research in crane safety.

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CHAPTER III
RESEARCH METHODOLOGY

In this chapter, explain the step of flowchart research methodology that includes the procedures for the final project. The steps in this research using the RCM method shown ini **Figure 3.1.**

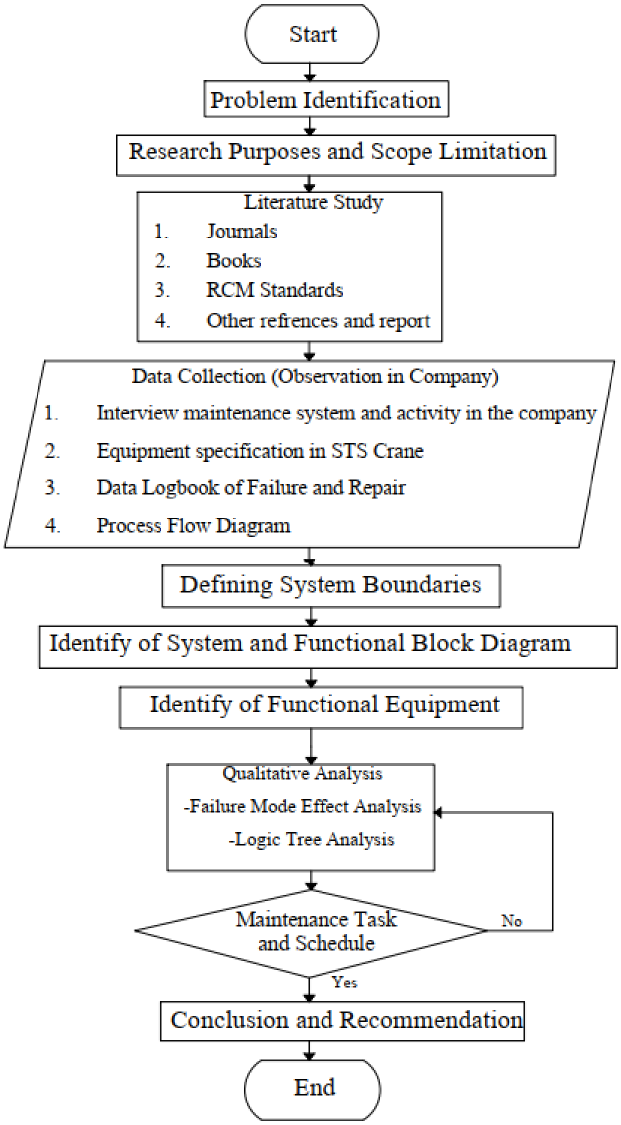

Figure 3.1 Flow Chart Thesis Work

3.1 Problem Idenfitication

At the first stage determine the problem that will be discussed in this thesis, namely based on the condition of maintenance management in STS Container Crane owned by PT. Terminal Teluk Lamong, which is caused by damage to some equipment such as motor hoist, motor trolley, spreader, and another equipment. In this study using the RCM method.

3.2 Goal Setting and Scope Limitation

Obtained through problem identification. The deliverable output of this thesis would be the maintenance task and schedule.

3.3 Literature Study

Literature study is conducted as supporting in achieving the objectives of the research by means of the basic theories and to determine the method of completion based on supporting information sourced from journals, books, standard RCM methods, reports and other references.

3.4 Data Collection – Observation in Company

After doing the literature study, selecting a system and collecting data performed. There are three categories to collect the data. The categories explained in down below.

3.4.1 Interview

- Maintenance Activity How the company maintain the relationship between the crew onboard and the operator
- Maintenance System How the company prevent failure with maintenance strategies

3.4.2 Data from the Company

- Equipment Specification: to know about the specification of each equipment that included into the Ship To Shore Container Crane
- Data Operational: to know about the operational history of each equipment. Such as running hours
- Data Failure & Repair (Log Book): to know the Time To Failure (TTF), Time To Repair (TTR) and down time in each component.
- Process Flow Diagram: to know the flow diagram of the system is consist of the Ship To Shore Container Crane

3.5 Defining System Boundaries

After obtaining the data from the related company and have understood the system of the RCM method, the next step is to set the system constraint that will be done on the three main systems in the STS Crane (refer to Table 2.2)

3.6 Identify of System and Functional Block Diagram

Functional Block Diagram (FBD) serves to describe a workflow system from the STS Crane at the time of operation. In essence, FBD describes an interconnectedness of functions between components that are formed in a working system, which includes also the function of each block.. Data from the function of each component of the equipment and how it operates is used to formulate definitions and basis determining for the effect and the order of a system failure[17].

3.7 Identify with Failure Mode Effects Analysis

To obtain the value of criticism on the components, it can be done by converting the value of probability rating against the value consequence rating that has been determined using the company's risk.

3.8 Maintenance Task and Schedule

Selection task is to determine if a cost effective maintenance task exists for each dominant failure cause[18]. It can be predictive or preventive maintenance based on cost effective maintenance are available or not. The result of this research is determine the maintenance task and schedule based on Failure Mode Effects Analysis and RCM II Decision Worksheet

3.9 Conclusion and Recommendation

Based from the result, the final step is make conclusion and giving recommendation for the company for preventive and corrective maintenance actions to prevent failures occur.

3.10 Research Schedule

Table 3.1 Research Schedule

No.	Research Plan	Month 1				Month 2				Month 3				Month 4			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Identification of problem research	■	■														
2	Literature Study	■	■	■													
3	Data Collection	■	■	■	■	■	■										
4	Identification of System Modelling, Functional Components					■	■	■									
5	Analysing Failure Modes Effects Analysis (FMEA)						■	■	■	■	■						
6	Analysing with Logic Tree Analysis									■	■	■	■	■			
7	Maintenance Task Allocation and Planning										■	■	■	■			
8	Conclusion & Recommendation													■	■		
9	Reporting					■	■	■	■	■	■	■	■	■	■	■	■

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[17] Moubray, J. 1997. Reliability-Centered Maintenance II, 2nd edition, Butterworth Heinemann, Oxford

[18] Wilmeth, Randall G., P.E, and Usrey, Michael W., Ph.D., P.E., C.P.I.M. December 2000 Evaluating A Reliability Centered Maintenance Program For Substation Equipment At New Century Energies.. Engineering Management Journal, Colorado.

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CHAPTER IV
DATA ANALYSIS

4.1 Data Collection

For conducting and support the research, basic information is obtained from the data collected in various sources from the journal literature, book, and company. The data consists of:

1. Guide book of Ship To Shore Crane
2. General design of the crane
3. Existing and planned maintenance report of the crane in every month and year.

4.2 Crane Details

1. Owner : PT. Terminal Teluk Lamong
2. Location : Surabaya
3. Type of crane : Ship To Shore Crane
4. Manufacturer : Konecranes

Figure 4.1 Cranes at Terminal Teluk Lamong

Table 4.1 Konecranes Particular

Source: Konecranes Guide Book Ship To Shore Gantry Crane

PANAMAX		
Lifting Capacity	:	40-50 tons
Dimensions		
Outreach	:	up to 13 rows
Lifting height	:	28-32 m
Speeds		
Gantry travel speed	:	45 m/ min
Hoisting speed empty	:	120 m/min
Hoisting speed laden	:	60 m/min
Trolley speed	:	150 m/min

Trolley Type	:	Semi-rope trolley or BoxHunter (with Active Load Control)
Spreader		
Spreader drive	:	Electrical (Hydraulic)
Floating twistlock	:	ISO
Positions	:	20ft, 30ft, 40ft, 45 ft, twin single, twin twenty and long twin
Quay Interface		
Rail span	:	15-23 m
Bogie arrangements	:	8 wheels per corner, or more depending on maximum admissible wheel loads
Typical wheel loads	:	35-45 tons/wheel
		30-40 tons/m

Table 4.2 STS Crane Components
Source: Konecranes Guide Book Ship To Shore Gantry Crane

STS Crane Components		
No.	Type	Function
1	Motor Hoist	As a gearbox drive for lifting the container
2	Motor Trolley	As a gearbox drive with horizontal movement
3	Coupling	As a connector from motor to gearbox using shaft
4	Gearbox	As a drum drive sling hoist and trolley
5	Drum Sling	As a sling container and for roll the sling
6	Wire Rope	To bind the load and move it controlled
7	Spreader	As a hook from sling and as a plate to lift containers
8	Limit Switch	As a overload indicator
9	Rail Brake	For braking on trolley movements
10	Motor Boom	To extend the arm of the crane
11	Motor Gantry	As a gearbox drive to configurate gantry with linear movement

4.2.1 Equipment Specifications on Crane

Before analyzing qualitatively, first explain the specifications of the equipment contained in the system. In the description there is an explanation of the usability when operating, functions and specifications.

- Electric Motor Specification:
  Manufacturer : Cavotec Specimas SpA
  Model : V100ML4/I-B5
  Power : 3kW, 400V, 50Hz
  Insulation : Class F
  Nominal speed : 1390rpm
  Nominal current : 6.45A @ 400V
  Electric motors when operated as moving gearboxes according to the type of mechanism on the hoist, trolley, or gantry. There are thermistors in the windings to avoid the motor condition from over temperature.

- Gearbox Specification:
  Manufacturer : Cavotec Specimas SpA
  Type : 3-stage bevel-planetary spur gearbox
  Model : T5.0
  Ratio : 1:21.2
  Main shaft : ID 63.5mm
  Overhung load : 1500kg
  In function, the gearbox is to transmit power from the motor and will drive the drum on a hoist, trolley and boom manner back and forth, up and down, or sideways corresponds to the mechanism.

- Drum Sling
  Manufacturer : Cavotec Specimas SpA
  Type : Monospiral
  Model : M2158-52GI
  Weight : 1680kg
  Drum slings used to hold the cable and rotate in the direction corresponding to the heavy equipment moving towards feedpoint.

- Spreader Specification
  Manufacturer: Stinis Holland BV
  Model: VATCVI-GLTW
  Single Operation: 20-40-45ft ISO
  Tare weight: 14300 kg
  Nummber of flippers: 4
  Working oil pressure: 90-130 bar
  Power suplly voltage: 400 VAC

- Wire Ropes Specification
  Rope type:
  30ZBB6x36WS+IWRCSZ Length: 258 m (2 pieces)
  30ZBB6x36WS+IWRCZS Length: 258 m (2 pieces)
  30ZBB6x36WSR-IWRC2160ZS Length: 237 m (2 pieces)

- Rail Brake Specification
  The rail brakes with type IRBN 560 are negative action brakes hydraulically released and mechanically operated. The maximum operating pressure is 21 MPA.

- Coupling
  Manufacturer: SPIDEX
  Couplings reduce intermittent short period torsional shocks. Any degree of uneven movement and load transference is consequently reduced. couplings contribute to noise reduction. Coupling transmits the torque safe against break-down.The operating temperatures are between - 40° and + 100°C. Short max. temperatures up to + 120°C are admissible.

- Limit Switch
  Manufacturer : Stromag AG
  Type : 48 turn geared rotary limit switch with 1+4 switches + transducer
  Model : 48BM 199/499 WGMU36
  Limit switches are installed on the hoist, troley and gantry mechanism to prevent damage due to over load or over travel.

4.3 Existing Maintenance

Analysis of the consequences of failure in determining the data required maintenance has been done by the company in the form of corrective and preventive, so that credible analysis results in accordance with field conditions. The following data are grouped according to repair time intervals, from monthly to annual.

Table 4.3 Existing Maintenance
Source: Monthly Report Maintenance STS Crane

Existing Maintenance Task		
No.	Preventive Existing Maintenance	Interval
1	Check hoist, gantry, trolley, boom drive	1 month
2	Check condition hoist, trolley, boom and grantry brake	
3	Check condition hoist and boom wire rope	
4	Check condition length screw machinery	
5	Check main cable reel	2 months
6	Check spreader cable reel	
7	Greasing pin & bearing gantry, girder, boom, trolley, spreader, and machinery area	3 months
8	Cleaning air filter machinery room	
9	Service all air conditioner	
10	Greasing hoist wire rope	
11	Check all system safety device	
12	Greasing boom wire rope	6 months
13	Check insulation hoist, gantry, trolley and boom motor	1 year
14	Check twistlock spreader dye penetrant test	
15	change gear box oil for hoist, gantry, trolley, boom system	
16	Change gear box oil for main cable reel	
17	Change gear box oil for spreader cable rel	
18	Change oil hydraulic spreader	
19	change oil thruster hoist, boom and rail gantry brake	
20	Change oil man lift gear box	2 years
21	Change oil emergency main and boom hoist gearbox	
22	change bearing fan motor hoist (A-M10 and A-M20)	
23	Change hoist and boom wire rope (inspection)	2-10 years

4.4 Functional Block Diagram

In the Functional Block Diagram, this will explain the working process flow from a crane power source until the operation of the container move will be depicted with a square symbol containing the component function and the arrow symbol as the process pointer. In this FBD, there are three processes in the operation of tower cranes, namely the hoist, trolley, and boom processes. Each process has several different equipment in carrying out the process. The results of the FBD are based on the guide book documents, literacy, and data from the crane maintenance operator.

4.5 Assets Hierarchy

Asset hierarchy is inter-connection information containing from top level to bottom, starting from the plan, the relevant departments, systems, sub-systems related to the object of research. Information is needed to see how the responsibilities of handling sub-system in case of failure. This hierarchy asset is displayed in Appendix 1 of this final project.

4.6 Assets Register

Asset register is further information in the form of a table of asset hierarchy that contains levels of each asset starting from level 1 to level 8 and equipment related to the tag of each component, made to determine the asset detail subsystem operating under the tag listed equipment. Asset register is shown in Appendix 1 of this thesis.

4.7 Failure Mode Effects Analysis (FMEA)

After compiling the asset register of the crane component that will be examined, the next step is to arrange the Failure Mode Effect Analysis (FMEA) using the standard RCM II John Moubray. FMEA focuses on the possible impact of equipment failure on the overall crane system. Here are the steps taken in the FMEA analysis:

1. Selection of components from crane system.
2. Identify the function, functional failure, failure mode of fuel oil system components.
3. Determine failure effect from impact of failure mode.

4.7.1 Identify Function of Each Component

First step of the FMEA is to identify function in each component of crane.

4.7.2 Identify Functional Failure

Second step is identify failures that have or will occur from each function. Malfunction contains information about the performance degradation of a component.

4.7.3 Identify Failure Mode

Failure mode is possible causes of the functional failure in each function of the equipment. To determine, failure mode need sources from guide book of Konecranes as comparative data with historical and plan of maintenance from STS Crane, and also several causes failure in general crane.

4.7.4 Determine Failure Effects

Failure effects is impact from the failure of component. Identifying the effects of failure must explain that the effect is whether the failure is hidden so that it cannot be detected, or will have the potential for human safety, the potential for performance degradation, the potential for damaging the environment or the potential for disruption of work operations that can result in stopping work. In this identification sourced from the guide book from the crane and the results of discussions with the maintenance manager.

Table 4.4 FMEA for Spreader

Information Reference			SYSTEM : Spreader SUBSYSTEM: Drive System				
Item Number	**FUNCTION**		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
1	1	To lift the container with the loking mechanism attached to the four corners, with maximum load 50-65 ton	A	Broken of twist lock	1	Operator's inaccuracy in placing container hole	Spreader can't lock the container
			B	The cable pin on the spreader panel doesn't detect voltage	1	There is no power on proximity sensor	Can't locked unlocked. Other impacts can drop the spreader which will injure operator safety.
					2	Not Correspond to the actual wiring position	

Table 4.5 FMEA for Wire Rope

Information Reference			SYSTEM : Wire Rope SUBSYSTEM: Drive System				
Item Number	**FUNCTION**		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens when it falls)**
2	1	To attach to a load and move it in a controlled matter. (max number of broken wires over 6 diameter or 30 x diameter)	A	The maximum number diameter of broken wires is more than 6 diameter or 30 x diameter	1	Loose outer strands	The spreader will fall if it is broken. Need to change the wire and will stop the operation within a period of one day. For losses are only delays in lifting the container. the operator can be injured due to being crushed by goods transported while under the crane. For the repair it takes 20 - 75 hours, depends on the failure rate
	2	To attach the load with local reduction of rope 7,5% in wire diameter	A	The local reduction of rope diameter less than 7,5%	2	Prostrusion of rope parts	

Table 4.6 FMEA for Motor Hoist

Information Reference			SYSTEM : Motor Hoist				
			SUBSYSTEM: Electrical System / Hoist Mechanism				
Item Number	**FUNCTION**		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
3	1	As a drive gear box to raise and lower material	A	Stuck while moving the drum	1	Damage bearing, motor axle broken, and increasing winding temperature	If the bearings used are not of good quality, they will wear out quickly. The increase in winding temperature of 10 degree celcius will affect the rate of decrease in insulation resistance by 50% under 5 MΩ.
	2	To move the drums vertically with speed at 150 m/min	A	cannot reach rotation at a speed of 150 m / min or overspeed	1	operating conditions which result in the motor current is greater than the ability (rated capacity).	If worn, the movement of two surfaces that touch each other will cause heat, so that over time it burns. Also, unable to move the gear box hoist and the hoist cannot run.

Table 4.7 FMEA for Gearbox

Information Reference			SYSTEM : Gearbox				
			SUBSYSTEM: Electrical System				
Item Number	**FUNCTION**		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
4	1	As a drum drive hoist	A	Unable to move trolley, hoist and slewing horizontally and vertically	1	Broken gearbox shaft	Jammed and cannot move
					2	Geardrive gear or rewind movement wear off	Does not work optimally

Table 4.8 FMEA for Coupling

Information Reference		**SYSTEM : Coupling**				
		SUBSYSTEM: Drive System				
FUNCTION		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
5	Couplings reduce intermittent short amount torsional shocks, by shortly storing elastically a part of shock energy. Couplings restrain body resonance and noise reduction.	A	Change in vibration from running noise	1	Loosened screw for securing hub axial	Danger of ignition due to hot surfaces and sparking, Increased temperatures at the spider surface;
				2	Misalignment and destructive of vibrations	
				3	Short-term torque transmission because of metal contact	
		B	Breaking of cams	1	Mistake in service of the unit causes jam of the coupling and break of the cams. Overload	
				2	Parameters from operating can't correspond to the performance of the coupling because size of copuling is small	
				3	Higher wear. During power transmission, metal contact in cams	
		c	Premature wear of spider	1	High temperatures	There is a danger of ignition can be caused by sparks if metal contacts the cams
				2	Agressive conditions of the enviroment cause by chemicals, steam and/or fluids	

Table 4.9 FMEA for Motor Trolley

Information Reference			SYSTEM : Motor Trolley SUBSYSTEM: Electrical System / Trolley Mechanism				
Item Number	**FUNCTION**		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
6	1	Move the trolley horizontally with speed at 150-180 m/min	A	cannot reach rotation at a speed of 150 m / min or overspeed	1	Motor does not work	If the bearings used are not of good quality, they will wear out quickly. If worn, the movement of two surfaces that touch each other will cause heat, so that over time it burns. Also, unable to move the trolley drive and cannot run. Cause the motor will be jammed in work.
	2	As a drive gear box for forward and reverse trolley	B	Hangs and cannot move and trolley cannot move	2	Damage bearing and motor axle broken	

Table 4.10 FMEA for Limit Switch

Information Reference			SYSTEM : Limit Switch SUBSYSTEM: Safety System				
Item Number	**FUNCTION**		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
7	1	Overload indicator and to give a precise indication of the amount of cable on the drum at any time.	A	Can't detect	1	Can't handled the load	Overload

Table 4.11 FMEA for Drum Sling

Information Reference			SYSTEM : Drum Sling SUBSYSTEM: Drive system				
Item Number	**FUNCTION**		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
8	1	Place for rolls and to extend the rope until length 23 m	A	Stuck while rolling or extending a rope	1	Rusty Drum Sling	Cannot extend a rope in length until 23m

Table 4.12 FMEA for Motor Gantry

Information Reference		SYSTEM : Motor Gantry SUBSYSTEM: Electrical System				
FUNCTION		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
9	Move the trolley horizontally with speed at 45 m/min	A	cannot reach rotation at a speed of 45 m / min or overspeed	1	Damage bearing	If the bearings used are not of good quality, they will wear out quickly. If worn, the movement of two surfaces that touch each other will cause heat, so that over time it burns. Also, unable to move the gantry and cannot travel.
				2	Motor does not work	

Table 4.13 FMEA for Rail Brake

Information Reference		SYSTEM : Rail Brake SUBSYSTEM: Drive System				
FUNCTION		**FUNCTIONAL FAILURE (Loss of function)**		**FAILURE MODE (Cause of failure)**		**FAILURE EFFECT (What happens whent it falls)**
10	For braking on trolley and gantry movements with range of brake air gap in 0.5-1.2 mm	A	There is oil on the friction plate	1	Oil pollution on friction plates is caused by improper installation.	Gantry Travel, Rail Brake Jammed

Table 4.14 FMEA for Motor Boom

<table>
<tr><th colspan="2">Information Reference</th><th colspan="6">SYSTEM : Motor Boom
SUBSYSTEM: Electrical System / Boom Mechanism</th></tr>
<tr><th colspan="2">FUNCTION</th><th colspan="2">FUNCTIONAL FAILURE (Loss of function)</th><th colspan="2">FAILURE MODE (Cause of failure)</th><th colspan="2">FAILURE EFFECT (What happens whent it falls)</th></tr>
<tr><td rowspan="3">11</td><td rowspan="3">to extend the arm of the crane up to 23m</td><td rowspan="2">A</td><td rowspan="2">Decrease in speed from normal conditions</td><td>1</td><td>Damage to motor insulation or low insulation resistance</td><td colspan="2" rowspan="3">Cause the motor to burn, cannot reach normal motor speed and unable to extend the crane's arm</td></tr>
<tr><td>2</td><td>environmental impact causes the entry of steam into the motor</td></tr>
<tr><td>B</td><td>Overheating</td><td>1</td><td>Overheat motor cause thermistor doesn't work</td></tr>
</table>

4.8 Proposed Task

Furthermore after FMEA has been completed, the next step is to analysis of the consequences and determine the maintenance task. In proposing maintenance measures refer to ISO 9927, ISO 4309, ISO 12488 standards, STS crane guide book, maintenance log book and Logic Tree Analysis on RCM II. Based from table of failure mode, in this step the percentage of failure consequences that include potential hidden failures, safety, environment and operations using Logic Tree Analysis. Logic Tree Analysis is shown in Appendix 2 and Appendix 3.

Table 4.15 Recapitulation Consequences of Failure Mode

Consequences Category		
Type	Amount	Percentage
Hidden	6	22%
Safety	4	15%
Environment	3	11%
Operation	14	52%
Total	27	100%

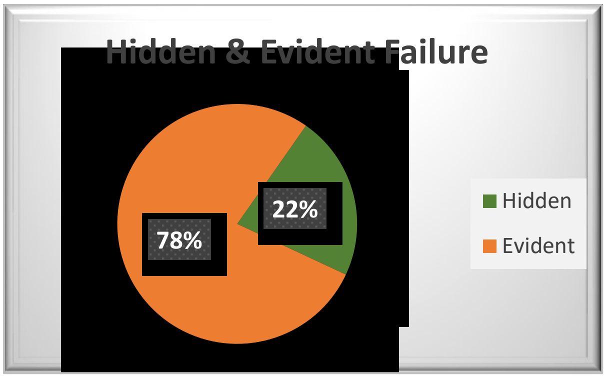

Figure 4.2 Hidden and Evident Failure

Based on Table 4.15 and Figure 4.2, identified 22% of the overall failure mode has a type of hidden failure, and 78% of failures based on evidence that includes 15% identified as safety failure, 11% identified as environment failure, and 52% identified as operation failure.

The most vulnerable to damage in the safety category that is on the spreader, because the harm to the operator on duty and could damage the containers being transported. The operational consequence category has the highest percentage of consequences because some equipment will completely stop the crane operation so that a breakdown occurs in minutes to hours, and can also be caused by operator negligence. From these results, the company will be recommended to identify and improvemet the maintenance.

Table 4.16 Recapitulation Proposed Maintenance Task Category

Maintenance Category		
Task Type	Amount	Percentage %
Scheduled On Condition Task	12	44%
Scheduled Restoration Task	0	0%
Scheduled Discard Task	12	44%
Failure Finding Task	3	11%
Redesign	0	0%
Combination	0	0%
Total Task	27	100%

The next step is determine the proposed task to determine the selection of the best maintenance tasks based on the results of the assessment of consequences. Based on the recapitulation results, it is found that the best selection of each category shows a figure of 44% for scheduled condition tasks, some of which refer to scheduling based on the conditions of the component and 44% for scheduled discard tasks, which some tasks refer to preventive actions for component replacement before the limit its age and not focused on the condition, and 11% for failure finding task, because some hidden failures cannot apply condition inspection or time based monitoring, which aims to test whether an asset is still working optimally or not. There are no allocation of tasks that must be redesigned, because the risk of damage is not related to crane design defects and the biggest cause is in operations. However, for the effectiveness of the results of the FMEA method recommendations to be carried out periodically and to follow the conditions of the component.

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CHAPTER V
CONCLUSION

5.1. Conclusion

Conclusions that can be taken from the final project using the Reliability-Centered maintenance method with qualitative analysis for determining the proposed Maintenance task of each failure mode and reduced the failures that has happened to Ship to Shore Crane are as follows:

1. Based on the analysis of FMEA contained in RCM II Worksheet shows that out of 11 components consisting of spreader, wire rope, gearbox, motor hoist, motor trolley, coupling, limit switch, drum sling, motor gantry and travel brake, there is a 27 total failure mode as the cause of the functional failure and will have an impact on the crane stopped operating for a while.

2. In the test results using Logic Tree Analysis, it was concluded that there are no maintenance task types in the form of scheduled restoration task, redesign and combination.

3. The type of type of treatment activities produced from each of the failure modes consist of 3 activities:

   a) Scheduled on condition task: This type of maintenance activity applies to components such as spreader, wire rope, noise checking on motor hoist, motor trolley, and motor gantry.

   b) Scheduled discard task: This type of maintenance activity applies to components such as gearbox to disassembly, changing bearing fan on the electric motor, and travel brake.

   c) Failure Finding Task: This type of maintenance activity applies to components such as for disassemble the drum sling to find rusty components, surge testing for insulation on motor.

5.2. Suggestion

Based on the results of this thesis, there are some recommendation for improvement maintenance of Ship To Shore Crane on PT. Terminal Teluk Lamong are as follows:

1. Recommended for the maintenance division of the crane system, re-evaluation is needed related to the preventive maintenance of each equipment to minimize the breakdown time in the middle of operation, based on the maintenance schedule that has been measured.

2. Qualitative analysis is also expected to be combined by the manufacturing data and quantitative analysis in the future to apply to other crane types and the

smallest equipment of every subsystem on the crane by recording the damage detail.

3. Needs more attention back to the component that has a defect that can not be known visual or hidden damage has consequences, so it needs demolition on a specific schedule before the defective component life.

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APPENDIX 1

DATA COLLECTION COMPANY

6.1 Step 1 – Data Collection of General Arrangement

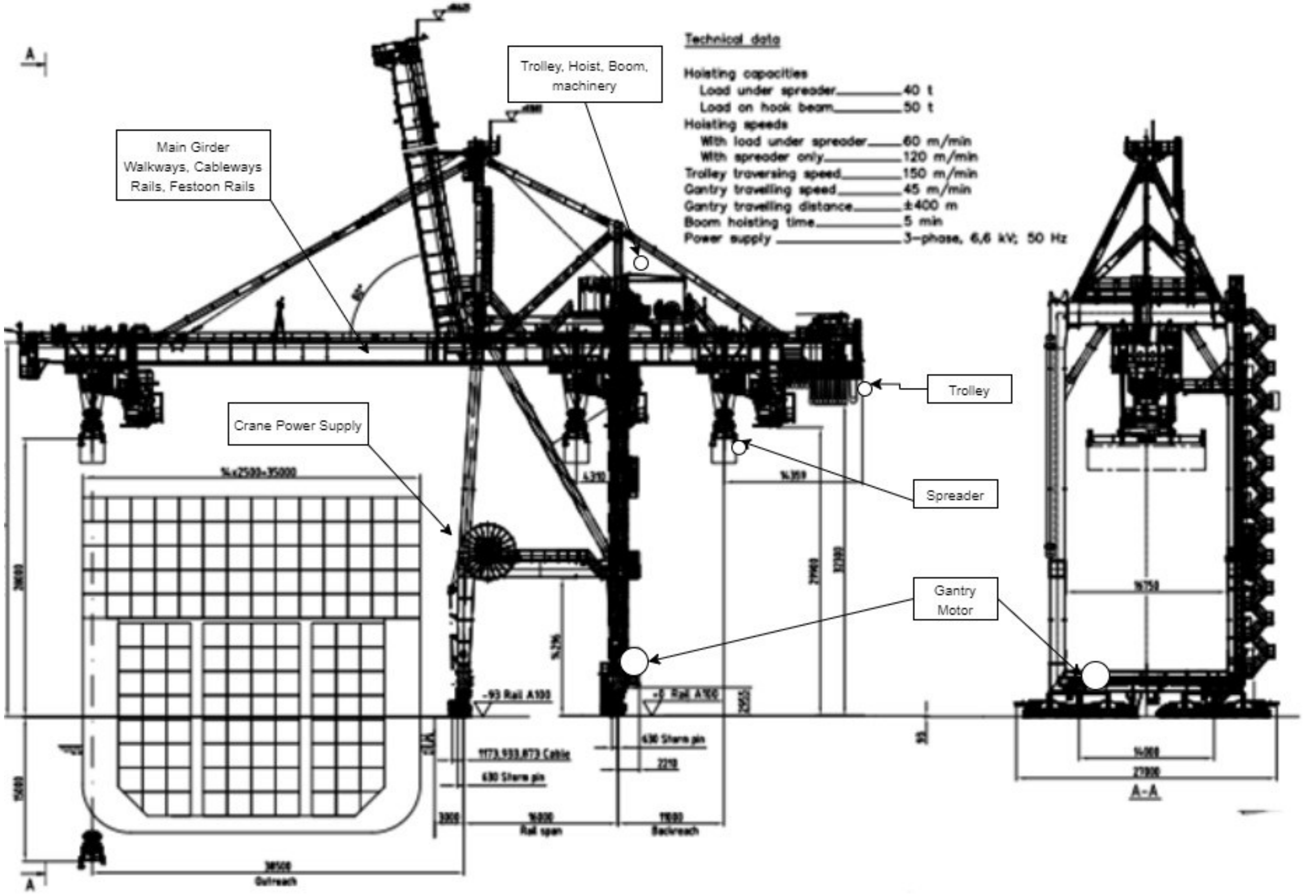
6.2 Step 2 – Data Collection of Assets Hierarchy

6.3 Step 3 – Data Collection of Assets Register

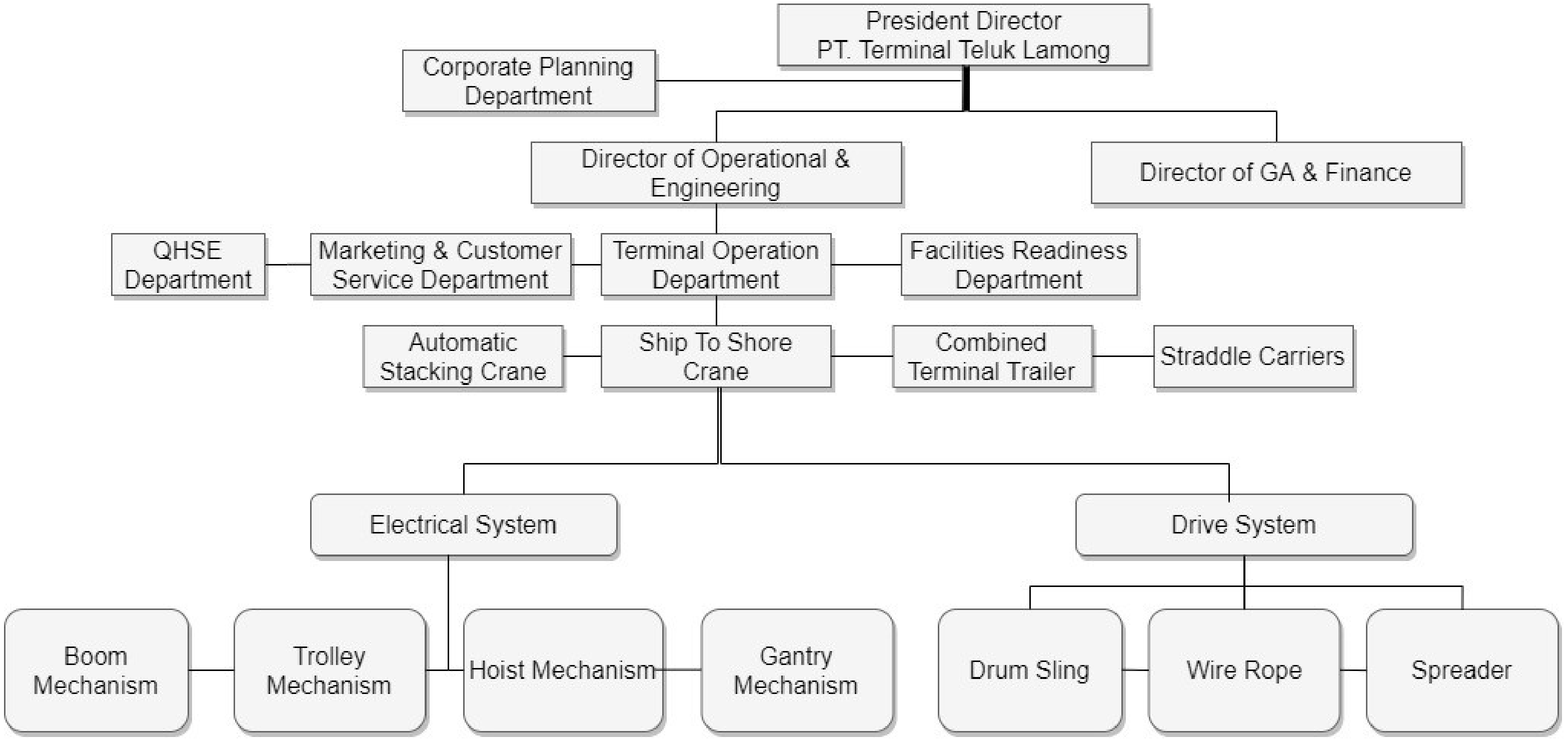
6.4 Step 4 – Making Functional Block Diagram

6.5 Step 5 - Data Collection of Total Breakdown Time

6.1 Data Collection of General Arrangement



6.2 Data Collection of Assets Hierarchy

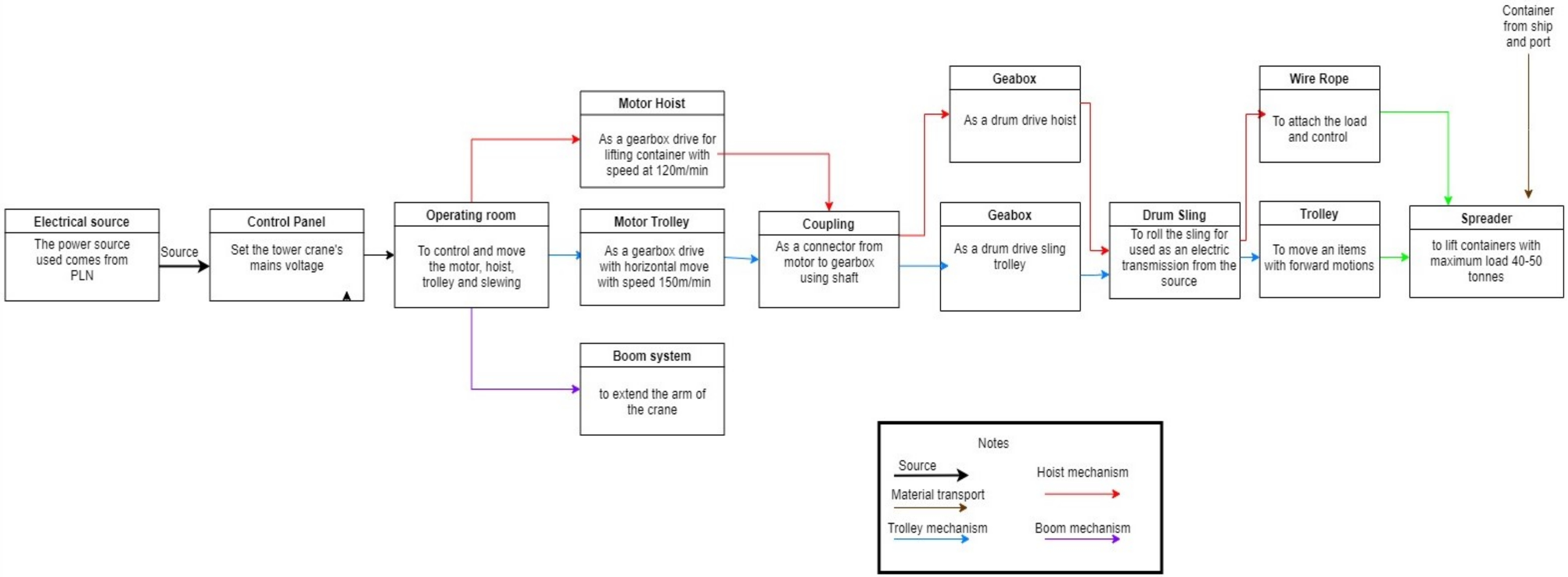


6.3 Data Collection of Assets Register

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	EQUIPMENT TAG
Plant	Operating Unit	Operating Area	System	Subsystem	Equipment		
Operational & Engineering Department Terminal Teluk Lamong							
	Terminal Operation Department						
		Ship To Shore Crane				STS I1 & STS I4	
			Electrical system				
				Motor			
					Electrical Motor	Motor Hoist 1	A1-M1
						motor Hoist 2	A1-M2
					Electrical Motor	Motor Trolley 1	E-M1
						Motor Trolley 2	E-M2
						Motor Trolley 3	E-M3
						Motor trolley 4	E-M4
					Electrical Motor	Motor Gantry 1	R1-M1
						Motor Gantry 2	R1-M2
						Motor Gantry 3	R1-M3
						Motor Gantry 4	R1-M4
						Motor Gantry 5	R1-M5
						Motor Gantry 6	R1-M6
						Motor Gantry 7	R1-M7

						Motor Gantry 8	R1-M8
					Electrical Motor	Motor Boom 1	P-M1
					Coupling	Coupling	
				Gearbox		Gear Box	T5.0
			Drive System				
						Drum Sling	
					Spreader		LBP 040-042
					Brake Motor		E-Y1
							E-Y2
							E-Y3
							E-Y4
					Pump motor		A-Y81
							A-Y82
			Safety System				
					Limit switch		S99-SG025-402

6.4 Functional Block Diagram



6.5 Data Collection of Total Breakdown Time

Unit	STS Crane 2018-2019												Total Down Time (hours)	Capacity Crane (hours)
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
STS 01-D	1.25	0.57	2.50	0	3.58	0	0	1.17	0	0.33	0.67	8.83	18.9	8856
STS 02-D	0	0.33	10.00	0.93	0	0	0	0	0.83	0	0	0	12.1	8856
STS 03-D	0	1.83	0	0	0	0.17	0	0	0	0	0.33	0.27	2.6	8856
STS 04-D	0	0.42	0	0.75	1.00	0	1.25	0	0.45	0	0	0	3.87	8856
STS 05-D	2.00	0	0	0	0.50	0	0	1.17	0.67	0.45	0	2.50	7.28	8856
STS 01-I	2.63	1.67	0.67	0.50	1.75	10.75	0	0.25	0	3.92	34.75	140.83	197.72	8856
STS 02-I	2.92	1.33	0.17	0	0	5.75	5.83	3.08	3.08	0.50	0.50	3.75	26.92	8856
STS 03-I	0.50	0	24.90	0.25	38.50	0.33	0	0	0	0.83	4.08	0.50	69.9	8856
STS 04-I	2.25	0.63	0.83	11.58	0.50	2.25	1.33	21.08	0.42	0.25	1.58	0.75	43.47	8856
STS 05-I	1.12	0.17	3.50	0.83	2.50	0.22	2.00	30.17	0.25	0	0.25	0	41	8856
TOTAL													**423.75**	**88560**

APPENDIX 2

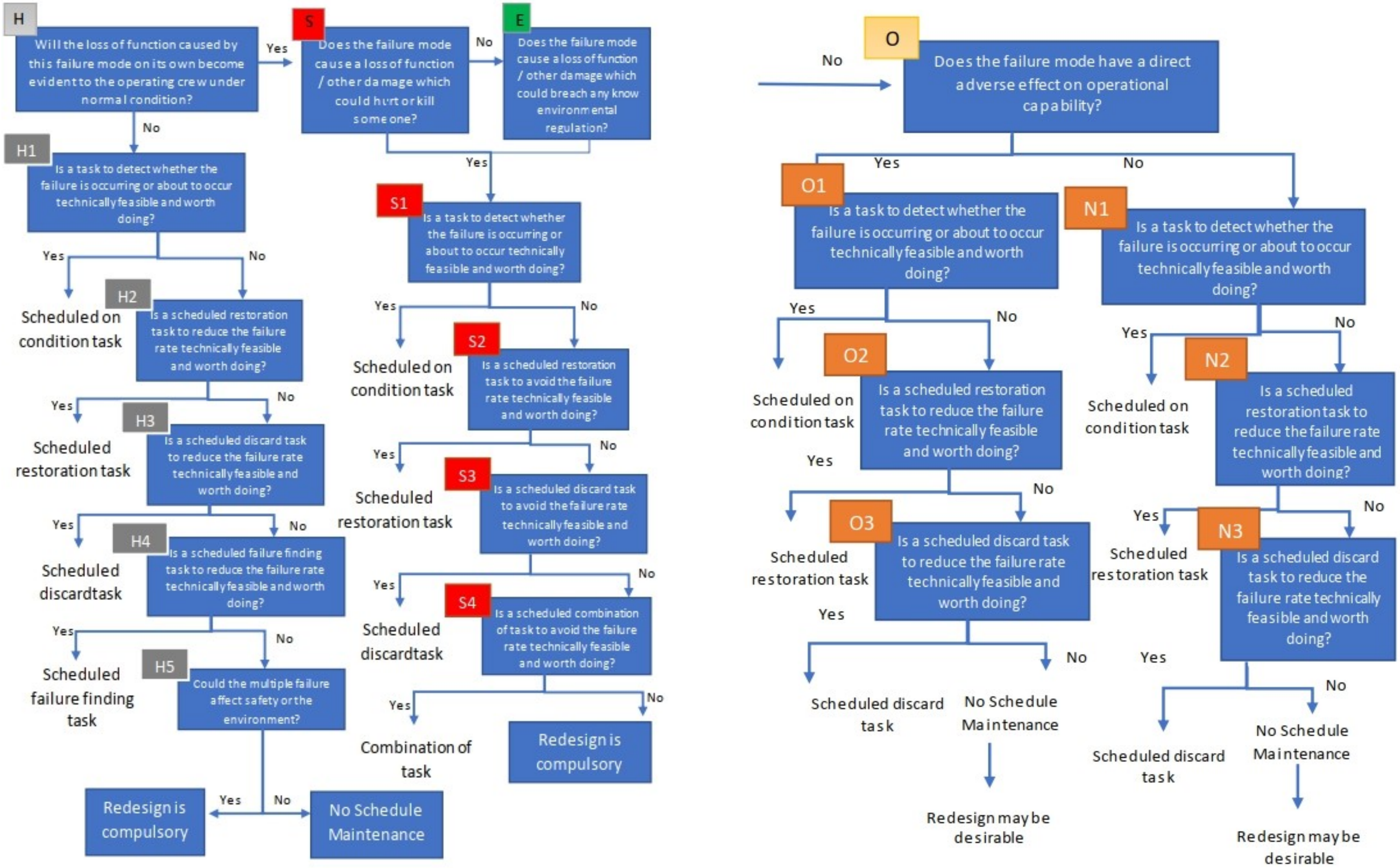
LOGIC TREE ANALYSIS

7.1 Step 1 – List question of Logic Tree Analysis

7.2 Step 2 – Determination consequences evaluation

7.3 Step 3 – Determinatiion of Proposed Task

7.1 List of question Logic Tree Analysis



HIDDEN									
H1	Is an on-condition task Technically feasible and Worth doing?	H2	Is a scheduled restoration task Technically feasible and Worth doing?	H3	Is a schedule discard task Technically feasible and Worth doing?	H4	Is a failure finding task Technically feasible and Worth doing?	H5	No scheduled maintenance
H1-A	Is there a clear potential failure condition?	H2-A	Is there a definable age where there is a rapid increase in the conditional probability of failure?	H3-A	Is there a definable age where there is a rapid increase in the conditional probability of failure?	H4-A	Is it posssible to check if the device has failed?		
H1-B	What is it?	H2-B	What is it?	H3-B	Do most failures occur after this age?	H4-B	Will the task prove the functionality of all components of the		
H1-C	What is the P-F interval?	H2-C	Do most failures occur after this age?	H3-C	Does this task reduce the risk of the multiple failure to a tolearable level?	H4-C	Is it practical to do the task at the required intervals?		
H1-D	Is the P-F interval long enough to be of any use?	H2-D	Will the task restore the item to its original condition?			H4-D	Can the task be done without significantly increasing the risk of the		
H1-E	Is it consistent?	H2-E	Does this task reduce the risk of the multiple failure to a tolearable level?			H4-E	Does this task reduce the risk of the multiple failure to a tolearable level?		
H1-F	Can the task be done at intervals less than the P-F interval?								
H1-G	Does this task secure the availability needed to reduce the probability of multiple failure to a tolearable								

SAFETY & ENVIRONMENT									
S1	Is an on-condition task Technically feasible and Worth doing?	S2	Is a scheduled restoration task Technically feasible and Worth doing?	S3	Is a schedule discard task Technically feasible and Worth doing?	S4	Is a failure finding task Technically feasible and Worth doing?	S5	Is a combination of any of the above tasks Technically feasible and Worth doing?
S1-A	Is there a clear potential failure condition?	S2-A	Is there a definable age where there is a rapid increase in the conditional probability of failure?	S3-A	Is there a definable age where there is a rapid increase in the conditional probability of failure?	S4-A	Is it posssible to check if the device has failed?	S5-A	Are both the tasks technically feasible?
S1-B	What is it?	S2-B	What is it?	S3-B	Do most failures occur after this age?	S4-B	Will the task prove the functionality of all components of the protective device?	S5-B	Does the combination of tasks reduce the risk of the multiple failure to a tolerable level?
S1-C	What is the P-F interval?	S2-C	Do most failures occur after this age?	S3-C	Does this task reduce the risk of the multiple failure to a tolearable level?	S4-C	Is it practical to do the task at the required intervals?		
S1-D	Is the P-F interval long enough to be of any use?	S2-D	Will the task restore the item to its original condition?			S4-D	Can the task be done without significantly increasing the risk of the multiple failure?		
S1-E	Is it consistent?	S2-E	Does this task reduce the risk of the multiple failure to a tolearable level?			S4-E	Does this task reduce the risk of the multiple failure to a tolearable level?		
S1-F	Can the task be done at intervals less than the P-F interval?								
S1-G	Does this task secure the availability needed to reduce the probability of multiple failure to a tolearable level?								

OPERATION					
O1/N1	Is an on-condition task Technically feasible and Worth doing?	O2/N2	Is a scheduled restoration task Technically feasible and Worth doing?	O3/N3	Is a schedule discard task Technically feasible and Worth doing?
O1-A / N1-A	Is there a clear potential failure condition?	O2-A / N2-A	Is there a definable age where there is a rapid increase in the conditional probability of failure?	O3-A / N3-A	Is there a definable age where there is a rapid increase in the conditional probability of failure?
O1-B / N1-B	What is it?	O2-B / N2-B	What is it?	O3-B / N3-B	Do most failures occur after this age?
O1-C / N1-C	What is the P-F interval?	O2-C / N2-C	Do most failures occur after this age?	O3-C / N3-C	Does this task reduce the risk of the multiple failure to a tolearable level?
O1-D / N1-D	Is the P-F interval long enough to be of any use?	O2-D / N2-D	Will the task restore the item to its original condition?		
O1-E / N1-E	Is it consistent?	O2-E / N2-E	Does this task reduce the risk of the multiple failure to a tolearable level?		
O1-F / N1-F	Can the task be done at intervals less than the P-F interval?				
O1-G / N1-G	Does this task secure the availability needed to reduce the probability of multiple failure to a tolearable level?				

EQUIPMENT: Spreader			
Level Consequences	F1		
	FFA	FFB	
	FM 1	FM 1	FM2
Hidden	Y	Y	Y
Safety	Y	Y	Y
S1	Y	Y	Y
S1-A	Y	Y	Y
S1-B	Y	Y	Y
S1-C	Y	Y	Y
S1-D	Y	Y	Y
S1-E	Y	Y	Y
S1-F	Y	Y	Y
S1-G	Y	Y	Y

EQUIPMENT: Wire Rope		
Level Consequences	F1	F2
	FFA	FFA
	FM 1	FM1
Hidden	Y	Y
Safety	N	N
Environment	N	N
Operation	Y	Y
O1	N	N
O2	N	N
O3	Y	Y
O3-A	Y	Y
O3-B	Y	Y
O3-C	Y	Y

EQUIPMENT: Motor Hoist		
Level Consequences	F1	F2
	FFA	FFA
	FM 1	FM1
Hidden	Y	Y
Safety	N	N
Environment	N	N
Operation	Y	Y
O1	N	Y
O1-A		Y
O1-B		Y
O1-C		Y
O1-D		Y
O1-E		Y
O1-F		Y
O1-G		Y
O2	N	
O3	Y	
O3-A	Y	
O3-B	Y	
O3-C	Y	

EQUIPMENT: Gearbox		
Level Consequences	F1	F2
	FFA	FFA
	FM 1	FM1
Hidden	Y	Y
Safety	N	N
Environment	N	N
Operation	Y	Y
O1	N	N
O2	N	N
O3	Y	Y
O3-A	Y	Y
O3-B	Y	Y
O3-C	Y	Y

EQUIPMENT: Coupling											EQUIPMENT: Motor Trolley		
F1											Level Consequences	F1	F2
Level Consequences	FFA			Level Consequences	FFB			Level Consequences	FFC			FFA	FFA
	FM 1	FM2	FM 3		FM 1	FM 2	FM3		FM 1	FM 2		FM 1	FM1
Hidden	N	N	N	Hidden	Y	Y	Y	Hidden	Y	Y	Hidden	Y	Y
H1	Y	N	N	Safety	N	N	N	Safety	N	N	Safety	N	N
H1-A	Y	Y	Y	Environment	N	N	N	Environment	Y	Y	Environment	N	N
H1-B	Y	Y	Y	Operation	Y	Y	Y	S1	N	Y	Operation	Y	Y
H1-C	Y	Y	Y	O1	Y	Y	Y	S1-A		Y	O1	N	Y
H1-D	Y	Y	Y	O1-A	Y	Y	Y	S1-B		Y	O1-A		Y
H1-E	Y	Y	Y	O1-B	Y	Y	Y	S1-C		Y	O1-B		Y
H1-F	Y	Y	Y	O1-C	Y	Y	Y	S1-D		Y	O1-C		Y
H1-G	Y	Y	Y	O1-D	Y	Y	Y	S1-E		Y	O1-D		Y
H2		N	N	O1-E	Y	Y	Y	S1-F			O1-E		Y
H3		Y	N	O1-F	Y	Y	Y	S1-G			O1-F		Y
H3-A		Y		O1-G	Y	Y	Y	S2	N		O1-G		Y
H3-B		Y						S3	Y		O2	N	
H3-C		Y						S3-A	Y		O3	Y	
H4			Y					S3-B	Y		O3-A	Y	
H4-A			Y					S3-C	Y		O3-B	Y	
H4-B			Y								O3-C	Y	
H4-C			Y										
H4-D			Y										
H4-E			Y										

EQUIPMENT: Limit Switch	
Level Consequences	F1
	FFA
	FM1
Hidden	N
H1	N
H2	N
H3	Y
H3-A	Y
H3-B	Y
H3-C	Y

EQUIPMENT: Drum Sling	
Level Consequences	F1
	FFA
	FM1
Hidden	N
H1	N
H2	N
H3	N
H4	Y
H4-A	Y
H4-B	Y
H4-C	Y
H4-D	Y
H4-E	Y

EQUIPMENT: Motor Gantry		
Level Consequences	F1	F2
	FFA	FFA
	FM 1	FM1
Hidden	Y	Y
Safety	N	N
Environment	N	N
Operation	Y	Y
O1	N	Y
O1-A		Y
O1-B		Y
O1-C		Y
O1-D		Y
O1-E		Y
O1-F		Y
O1-G		Y
O2	N	
O3	Y	
O3-A	Y	
O3-B	Y	
O3-C	Y	

EQUIPMENT: Rail Brake	
Level Consequences	F1
	FFA
	FM1
Hidden	N
H1	N
H2	N
H3	Y
H3-A	Y
H3-B	Y
H3-C	Y

EQUIPMENT: Motor Boom			
Level Consequences	F1		
	FFA		FFB
	FM 1	FM2	FM 1
Hidden	N	Y	Y
Safety		N	Y
Environment		Y	
Operation			
H1	N		
H2	N		
H3	N		
H4	Y		
S1/E1		Y	N
S2/E2			N
S3/E3			Y

APPENDIX 3

DATA COLLECTION COMPANY

8.1 Step 1 – Making Information Worksheet RCM II
8.2 Step 2 – Making Maintenance Task Workpackage

8.1 Information Worksheet RCM II

The final step after determining the value of the consequences of each failure mode that is arranged on one sheet worksheet RCM II. This worksheet will facilitate the work of the engineers to analyze the work of maintenance of any equipment. In a worksheet sheet must contain information on the functional failure, failure mode, the value of the consequences, the proposed task, the interval time, and executing maintenance work.

RCM DECISSION WORKSHEET					System: Ship To Shore Crane 50-65ton										Facilitator:	Date	Sheet
					Sub System Function: Lifting and moving the container										Auditor:	Date	Of:
Information Reference					Consequences Evaluation				H1 S1	H2 S2	H3 S3	Default action			Proposed Task	Initial Interval (hour)	Can Be Done By
Item Number	Equipment	F	FF	FM	H	S	E	O	O1 N1	O2 N2	O3 N3	H4	H5	S4			
1	Spreader	1	A	1	Y	Y			Y						Scheduled on condition task: routine check twistlock	2160	Operator / BIMA Maintenance Division
			B	1	Y	Y			Y						Scheduled on condition task: routine check electrical cabinet		
				2	Y	Y			Y						Scheduled on condition task: change solenoid valve flipper, routine check		
2	Wire Rope	1	A	1	Y	N	N	Y	N	N	Y				Scheduled discard task: change the wire with the new one	2160	Mechanic / BIMA Maintenance Division
		2	A	1	Y	N	N	Y	N	N	Y				Scheduled discard task: greasing wire rope, routine check	4320	

RCM DECISSION WORKSHEET					System: Ship To Shore Crane 50-65ton											Facilitator:		Date	Sheet
					Sub System Function: Lifting and moving the container											Auditor:		Date	Of:
Information Reference					Consequences Evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default action			Proposed Task		Initial Interval (hour)	Can Be Done By	
Item Number	Equipment	F	FF	FM	H	S	E	O				H4	H5	S4					
3	Motor Hoist	1	A	1	Y	N	N	Y	N	N	Y				Scheduled discard task: loose electric, change bearing fan motor		8640	Electrician / BIMA Maintenance Division	
		2	A	1	Y	N	N	Y	Y						Scheduled on condition task: check noise from the motor,		720		
4	Gearbox	1	A	1	Y	N	N	Y	N	N	Y				Scheduled discard task: disassembly of the gearbox, gear shifting, lubrication, routine checking		2160	Mechanic / BIMA Maintenance Division	
				2	Y	N	N	Y	N	N	Y				Scheduled discard task: disassembly of the gearbox, gear shifting, lubrication, routine checking		4320		

RCM DECISSION WORKSHEET					System: Ship To Shore Crane 50-65ton											Facilitator:	Date	Sheet
					Sub System Function: Lifting and moving the container											Auditor:	Date	Of:
Information Reference					Consequences Evaluation				H1 S1	H2 S2	H3 S3	Default action				Proposed Task	Initial Interval (hour)	Can Be Done By
Item Number	Equipment	F	FF	FM	H	S	E	O	O1 N1	O2 N2	O3 N3	H4	H5	S4				
5	Coupling	1	A	1	N				Y							Scheduled on condition task: check alignement and coupling parts	720	Mechanic / BIMA Maintenance Division
				2	N				N	N	N	Y				Failure finding task: check alignement, driving units and find out the reason for the vibrations		
				3	N				N	N	Y					Scheduled discard task: check alignment, change the old spider	8640	
			B	1	Y	N	N	Y	Y							Scheduled on condition task: check alignement and driving units	720	
				2	Y	N	N	Y	Y							Scheduled on condition task: check alignement and driving units		

				3	Y	N	N	Y	Y						Scheduled on condition task: check alignement and driving units		
			C	1	Y	N	Y		N	N	Y				Scheduled discard task: change the spider, visual check	4320	
				2	Y	N	Y		Y						Scheduled on condition task: check condition of environment	720	

RCM DECISSION WORKSHEET	System: Ship To Shore Crane 50-65ton	Facilitator:	Date	Sheet
	Sub System Function: Lifting and moving the container	Auditor:	Date	Of:

Information Reference					Consequences Evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default action			Proposed Task	Initial Interval (hour)	Can Be Done By
Item Number	Equipment	F	FF	FM	H	S	E	O				H4	H5	S4			
6	Motor Trolley	1	A	1	Y	N	N	Y	N	N	Y				Scheduled discard task: loose electric, change bearing fan motor	8640	Electrician / BIMA Maintenance Division
				2	Y	N	N	Y	Y						Scheduled on condition task: check noise from the motor, check RPM of the motor	720	
7	Limit Switch	1	A	1	N				N	N	Y				Scheduled discard task: do replacement limited switches that are broken, calibrate	3840	Operator / BIMA Maintenance Division
8	Drum Sling	1	A	1	N				N	N	N	Y			Failure Finding Task: disassemble the drum sling to find rusty components.	720	Mechanic / BIMA Maintenance Division

RCM DECISSION WORKSHEET	System: Ship To Shore Crane 50-65ton	Facilitator:	Date	Sheet
	Sub System Function: Lifting and moving the container	Auditor:	Date	Of:

Information Reference					Consequences Evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default action			Proposed Task	Initial Interval (hour)	Can Be Done By
Item Number	Equipment	F	FF	FM	H	S	E	O				H4	H5	S4			
9	Motor Gantry	1	A	1	Y	N	N	Y	N	N	Y				Scheduled discard task: loose electric, change bearing fan motor	8640	Electrician / BIMA Maintenance Division
				2	Y	N	N	Y	Y						Scheduled on condition task: check noise from the motor, check RPM of the motor	720	
10	Rail Brake	1	A	1	Y	N	N	Y	N	N	Y				Scheduled discard task: replacement of brake pads, routine check	720	Mechanic / BIMA Maintenance Division
11	Motor Boom	1	A	1	N				N	N	N	Y			Failure Finding Task: rewinding, surge testing	3840	Electrician / BIMA Maintenance Division
				2	Y	N	Y		Y						Scheduled on condition task: routine check, check noise	720	
			B	1	Y	Y			N	N	Y				Scheduled discard task: loose electric, change thermistor motor protection		

8.2 Maintenance Task Workpackage

Maintenance tasks and scheduling are products of RCM II to finally be executed by the operator in the effectiveness of maintenance activities on each equipment. Based on guide book, major overhaul carried out every 10 years of operation, with the following activities:

1. The complete dismantling of machinery.
2. The cleaning of all machinery
3. The replacement of all defective components.
4. The re-assembly of the machinery

Maintenance Schedule			
SPREADER			
Interval		Done by	Equipment tag
Every Week		Operator	
The following are maintenance task recommendations and scheduling that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:			References Failure Mode
1	Check that the twistlocks are not damaged.		1.A.1
2	Check that the "landed" feeler pins are not damaged or seized.		
3	Check that the cable is correctly wound onto basket in the		
Interval			
2 - 3 months			
1	Check spreader cable reel		1.B.1
2	Check twistlock spreader dye penetrant test		1.A.1
3	Check solenoid valve flipper		1.B.2
4	Check telescopic beam unit		
5	Check electrical cabinet		1.A.1
6	Check cable StiCAN		
Interval			
Every Year			
1	Change oil hydraulic spreader		1.B.1

Maintenance Task Schedule			
MOTOR HOIST			
Interval		Done by	Equipment tag
Every Month		Electrician	A1-M1, A1-M2
The following are maintenance task recommendations and scheduling that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:			References Failure Mode
1	Inspect condition of motor hoist by maintaining the insulation resistance value at 5 mega ohms and a voltage of 1000 volts		2.A.1
2	Check speed machine		
3	Check noise		
4	Clean cooling air passages using low-pressure water spray.		
5	Ensure that all electrical connections are properly tightened.		
6	Ensure that the encoder (if fitted) is properly fixed to the motor shaft.		1.A.1
7	Ensure that the brake (if fitted) is functioning correctly.		
8	The ball bearings are sealed for life, and therefore maintenance free.		
9	Check condition of hoist drive		
Interval			
3 months			
1	Greasing pin and bearing hoist		1.A.1
Interval			
Every year			
1	Change bearing fan motor		1.A.1

Maintenance Schedule			
COUPLING			
Interval		Done by	Equipment tag
every month		Mechanic	A15-A125
The following are maintenance task recommendations that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:			References Failure Mode
1	Check the alignement of the coupling		1.A.1
2	To identify alignment, use vibration and thermography analysis		1.A.2
Interval			
6 months			
1	Routine Lubrication		1.B.1
2	Visual check of the spider circumferential backlash must be done		1.C.1
Interval			
Every year			
1	The tightening torque of screws must be as indicated		1.C.2
2	Check the position of the indicator mark, prevent the wear		1.C.1
3	Control and replace the seals		1.A.3
4	Coupling disassembly		

Maintenance Schedule		
MOTOR TROLLEY		
Interval	Done by	Equipment tag
Every Month	Electrician	E-M1,M2,M3,M4
The following are maintenance task recommendations and scheduling that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:		References Failure Mode

1	Inspect condition of motor trolley	2.A.1
2	Check speed machine	
3	Check cooling blower	
4	Check rotor shaft	
5	Check insulation trolley motor	
6	Ensure that all electrical connections are properly tightened.	1.A.1
7	Ensure that the encoder (if fitted) is properly fixed to the motor shaft.	
8	Ensure that the brake (if fitted) is functioning correctly.	
9	Check condition of trolley drive	
Interval		
3 months		
1	Greasing pin and bearing Trolley	1.A.1

Maintenance Schedule		
DRUM SLING		
Interval	Done by	Equipment tag
Every Month	Mechanic	
The following are maintenance task recommendations that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:		References Failure Mode

1	Make sure that the gantry travel and cable reel drive are prevented from	1.A.1
2	Check the gap between spokes at the inner and outer ring cable diameter	
3	Check the drum width, especially at the outer rim	
4	Verify the tightness of all fasteners.	

Maintenance Schedule			
RAIL BRAKES			
Interval		Done by	Equipment tag
Every Week		Mechanic	E-Y1,Y2,Y3,Y4
Following these recommended steps should help operators reduce problems with V-belt drives. Here is a brief check list:			References Failure Mode
1	Check that there is no mechanical damage.		1.A.1
2	Check the oil level of thrusters.		
3	Check that there are no loose or missing fixings.		
4	Check that there are no leaks from the brake release thrusters.		
5	Check that there are no broken rails		

Maintenance Schedule			
WIRE ROPE			
Interval		Done by	Equipment tag
Every 3 months		Mechanic	
The following are maintenance task recommendations and scheduling that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:			References Failure Mode
1	Check condition of wire rope		2.A.1
2	Check if any deterioration or deformation		
3	Greasing boom and hoist wire rope		
Interval			
Every 2 years			
1	Change wire rope		1.A.1

Maintenance Schedule		
GEARBOX		
Interval	Done by	Equipment tag
Every 3 months	Mechanic	T5.0
The following are maintenance task recommendations and scheduling that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:		References Failure Mode
1	Check the vibration	1.A.1
2	Routine lubricate	
3	Visual inspection	
4	Checking for fatigue on the ball bearings such as cracking or flaking, and cracks	1.A.2
Interval		
Every 2 years		
1	Check the oil level of gearboxes	1.A.1

Maintenance Schedule		
MOTOR GANTRY		
Interval	Done by	Equipment tag
Every Month	Electrician	E-M1,M2,M3,M4
The following are maintenance task recommendations and scheduling that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:		References Failure Mode
1	Check noise from the motor	1.A.2
2	Check the brake pad condition	
3	Check noise from the wheels bearing	1.A.1
4	Check visual encoder gantry	1.A.2

Maintenance Schedule			
MOTOR BOOM			
Interval		Done by	Equipment tag
Every Month		Electrician	P-M1
The following are maintenance task recommendations and scheduling that can reduce the risk of failure and effectiveness in carrying out maintenance by the operator:			References Failure Mode
1	Inspect condition of motor trolley		1.A.2
2	Check speed machine		
3	Check cooling blower		
4	Check current		
5	Check insulation boom motor		1.A.1
6	Ensure that all electrical connections are properly tightened.		1.B.1
7	Ensure that the thermistor motor protection with good condition		
8	Clean if any steam left from the environment comes in		1.A.2
Interval		Done by	
Every 6 Months		Maintenance Division	
1	rewinding and surge testing		1.A.1

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The Author’s name is Almas Brilliano, born in Yogyakarta on 11 Januari 1998. As the oldest child from 2 siblings. The author fortunate to have a formal education at Al Azhar Syifa Budi Cibubur Cileungsi elementary school, Al Azhar Syifa Budi Cibubur Cileungsi junior high school, and Labcshool Cibubur senior high school. After graduated from Labschool Cibubur senior high school in 2016, author proceed to pursue bachelor degree at Department of Marine Enginering (Double Degree Program with Hochschule Wismar), Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember Surabaya specializes in Digital Marine Operation and Maintenance field. During the study period, Author did activities in campus organizations such as: UKM Musik ITS as a Vice President (2017-2018), Himpunan Teknik Sistem Perkapalan as a staff (2019-2020), and member of DMOM Laboratory (2019-2020). The Author also joined in several event organizers such as Committee in Pekan Seni Mahasiswa ITS 2018 and volunteer in Jazz Traffic festival 2019.

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