Integration of RAM Model and DES Method in Assessing Plant Utilization

By

Muhamad Shukri Bin Hassan
22856

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Mechanical Engineering
With Honours

JANUARY 2020

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CERTIFICATE OF APPROVAL

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Approved by,

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BANDAR SERI ISKANDAR, PERAK

January 2020

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(MUHAMAD SHUKRI BIN HASSAN)

ABSTRACT

This Final Year Project (FYP) entitled Integration of RAM Model and DES Method in Assessing Plant Utilization. Main motivation of this project is about plant utilization in oil and gas refinery plant. Plant utilization is an important indicator for a company to measure the production rate, operation safety and operation's availability. Nevertheless, the percentage of plant utilization will be reduced due to the unplanned operation shutdown and slowdown. Basically, the unplanned shutdown occurs when the production units completely stopped unexpectedly due to failure of major components in main equipment which required a significant of time to repair. Meanwhile, the unit slowdown means the production unit incapable to produce the targeted number of products per day. It is quite tough for the company to cater these unfavourable events because there are numerous of production unit, equipment and components in the refinery plant. Thus, this study had focused to assess the plant utilization of oil and gas refinery by using two approaches to model the performance of refinery plant which are RAM model and DES method. RBD simulation model has been selected as a tool for the RAM model analysis which was carried out with the aid of Weibull++ and BlockSim. The RBD simulation represented a static model of refinery plant which it focused more on the plant availability. Meanwhile, the DES method represented a dynamic model of refinery plant which it focused more on the production throughput which been carried out with the aid of Weibull++ and FlexSim. Based on the RBD simulation result, the highest internal failure contribution for production unit is crude reformate unit (CRU-1). Therefore, further study for equipment performance had been conducted and had identified the critical equipment quantitatively. Refrigeration Equipment (A-1308) and Recycled Gas Compressor (K-1301) had been highlighted as critical equipment due to high failure rate and significant downtime to do corrective maintenance. The performance of production unit as being enhance by prolonging the critical equipment's MTBF and reducing their MTTR. Thus, this study had shown that the RAM model is proficient to do 'what-if' analysis to provide improvement strategy options to maintenance team in-order to achieve the targeted production unit availability.

ACKNOWLEDGEMENT

I begin this paper with Allah's blessed names. We praise Him, we glorify Him as He ought to be praised and glorified. With His strengths and knowledges, I managed to survive by completing Final Year Project (FYP) dissertation report. Then, pray for peace and blessings for all His noble messengers in particular on the last of them all, the blessed Prophet Muhammad ﷺ.

First and foremost, I would like to express my gratitude to the most important person throughout the FYP period, Assoc Prof Dr. Masdi Bin Muhammad as my FYP Supervisor (SV) for his superb supervision, advices and recommendations. Thank you for the countless hours in knowledge and valuable experiences sharing throughout the supervision.

Special appreciation to Dr. Ainul Akmar Binti Mokhtar who also had contributed to make this project successful. Next, I do not forget supports from my family members who always be my back bones to face the challenges while executing this project. Last but not least, thanks to all my friends because their constructive recommendations, cooperation and encouragement had inspired me to complete this project. May Allah bless them all.

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RAM	Reliability, Availability and Maintainability.
DES	Discrete Event Simulation
RBD	Reliability Block Diagram
ECA	Equipment Criticality Analysis
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
MTTF	Mean Time To Fail
FMEA	Failure Mode and Effect Analysis
TBF	Time Between Failure
TTR	Time To Repair

CHAPTER 1

INTRODUCTION.

1.1 Background Study

Plant utilization is one of the important Key Performance Index (KPI) for a plant to measure the production rate, operation safety and operation's availability especially for oil and gas refinery plant. It is important because the plant utilization of refinery plant could directly impact the revenue of the company. Thus, it is essential for the researcher to develop a model which represent the performance of refinery plant in-order to analyse the operation bottlenecks, identify critical equipment and estimate the performance of refinery in future which could lead for the plant improvement strategy planning. For this project, the researcher had implemented two approaches in-order to model the performance of refinery plant which are RAM model and DES method.

RAM model is a Reliability, Availability and Maintainability model where the model is developed by referring to RAM study. RAM study is the best approach for this project because it could identify weak points with respect to failure and repair time that affected plant availability quantitatively, hence by using this approach will able to make effective actions and solutions in-order to improve plant availability (Corvaro, Giacchetta, Marchetti & Recanati, 2017). In addition, the RAM model conceivable to quantify and assess plant operational issues and be a strategic tool for management to optimize plant utilization by focusing on plant availability.

There are many types of RAM model has been developed in industry such as Markov chain, Petri-Net and Reliability Block Diagram (RBD) (Barberá, Crespo, Viveros & Kristjanpoller, 2012). For this project, the researcher had selected RBD to assess the plant utilization of refinery because this tool has an ability to quantify the availability of production unit, equipment and component. According to Catelani, Ciani and Venzi (2019), RBD is a combination of the components functional diagrams which contributes to the failure or success of the whole system. Furthermore, RBD can identify the consequences on the system if the failure occurs on the components.

Discrete Event Simulation (DES) method is a method which shows the sequences of each event at a certain point of changes level that occur in the system in a discrete time (Sumari, Ibrahim, Zakaria, & Hamid, 2013). Other than that, DES method can assess the plant utilization by focusing more on the throughput in refinery plant. Therefore, this method can be applied to determine the operation's bottleneck which effected the rate of production. Next, advantages of using DES method are the user can easily understand the throughput process flow with aid of animations in the software and it also have unlimited flexibility to declare input.

Before start to develop the model, the researcher had set-up certain characteristics of the model which must reflect the performance of plant utilization desired by the refinery company. First, there are numerous and various of production unit and equipment in refinery plant, thus it is fundamental for the researcher to set a failure definition for it. For this project, the production unit will be considered as failure when the production unit failed to produce actual throughput more than 90% from the planned throughput capacity. Meanwhile, for the equipment will be considered as failure when it failed and effected the unit production by failing to produce more than 90% from the planned throughput. Basically, this event is called as unplanned shutdown and slowdown. Second model characteristic, the model has been simulated on daily basis and the time of simulation had been counted as per day.

1.2 Problem Statement

First problem about this project is the measured plant utilization (%) is not reflecting to the measured reliability (%) of the refinery plant which been shown the example in Figure 1.1. Thus, the measured reliability incapable to assist the management team to monitor the plant utilization of refinery plant. As consequence, the management team lack of tools to assess the plant utilization which could be used for refinery's improvement strategy.

Key Performance Indicators	Unit	Mar-19	Apr-19		
		Act.	Act.	KPBI	
Process Utilisation (PU)					
Complex	%	95.5	95.2	95.5	
PSR-1	%	98.4	94.4	95.7	
PSR-2	%	93.8	94.6	95.4	
MG3	%	106.2	105.3	97.1	
Reliability					
PSR-1	%	98.7	98.8	98.6	
PSR-2	%	99.8	100.0	98.0	
MG3	%	100.0	100.0	98.5	

Figure 1.1: Key performance indicators for refinery plant in Melaka

Secondly, the refinery plant did not rank the criticality of refinery process unit, equipment and component quantitatively. Current practice, the refinery prioritized the equipment qualitatively using Equipment Criticality Analysis (ECA) method. In table 1.1 had shown the example of equipment in crude distillation unit being classified into ECA value which had taken example from Melaka refinery sweet crude distillation unit. C1 value indicates that the equipment is critical because the equipment had frequently failed and it has direct impact to the production line with high consequences of the failure. In other words, if the C1 equipment fails, the production line will be disturbed which could result of unit unplanned shutdown or slowdown. The slowdown and unplanned shutdown are very unfavourable events in refinery plant because it could lead to production loss and additional cost to repair the failure. By using the qualitative criticality ranking, the operation and maintenance team cannot focus to improve critical equipment with the total number 171 of C1 equipment.

Table 1.1: Equipment classification according to ECA value

ECA Value	TOTAL number of equipment in distillation unit.
C1	171
C2	186
C3	575

1.3 Objectives

In conjunction with above problem statement, the objectives of this project are:

1. To assess plant utilization of sweet crude refinery plant by developing RAM and DES model based on the stated model characteristics.
2. To determine the critical unit, equipment and component in the refinery plant quantitatively.
3. To perform ‘what-if’ analysis in component level.

1.4 Scope of Study

The project is limited to the following of scope of study which being tabulated in Table 1.2:

Table 1.2: Scope of study

No.	Tasks	Purpose	Level execution	Related software
1.	Conduct RAM study for production units in sweet crude refinery plant.	To determine critical production unit quantitatively.	Unit level	- MS Excel - BlockSim - Weibull++
2.	Implement RAM modelling for equipment in the most critical production unit.	To determine critical equipment quantitatively.	Equipment level	- MS Excel - BlockSim - Weibull++
3.	Execute RAM analysis for component in the most critical equipment.	To perform 'what-if' analysis.	Component level	- MS Excel - BlockSim - Weibull++
4.	Conduct DES model for crude distillation unit.	To simulate throughput of crude distillation unit.	Unit level	- MS Excel - FlexSim - Weibull++

CHAPTER 2

LITERATURE REVIEW

Plenty of research had been conducted to model the performance of refinery plant. There are several main points from the research need to be highlighted in this literature review section such as oil and gas refinery plant, failure rate, RAM study, Reliability Block Diagram (RBD) and DES method.

2.1 Oil and Gas Refinery Plant

As been mentioned earlier, the project's problem statements are regarding the management team is lack of tool to assess the plant utilization of refinery plant and determine critical production unit and equipment quantitatively. Thus, extensive research had been done to further understand about the KPI and facilities in refinery plant.

2.1.1 Plant Key Performance Index (KPI)

In all refinery plant will measure plant utilization as one of the KPIs for the plant because plant utilization indicates how well the performance of the refinery plant. The main idea about the KPI is to assist the management of business improvement. In Figure 2.1 had shown the simple flow chart about how KPI can be developed (EN ISO 14224:2016). The KPI should be aligned to the objectives of the company. Therefore, the company is free to define the KPIs in whatever way best contributes to the improved performance of the company because the improvement is an essential ingredient of successful companies. In addition, reliability and maintenance data can be used for developing and managing KPIs (EN ISO 14224:2016).

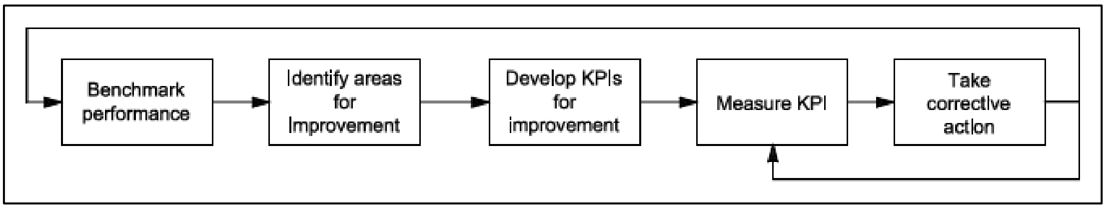

Figure 2.1: Process for using KPI to improve business performance (EN ISO 14224:2016)

For this project, it is possible for the researcher to establish a tool to assess the plant utilization of refinery plant by using RAM model as an approach to develop and manage the KPI. The model had used production unit performance data which sourced from Melaka refinery plant production unit failure data.

2.1.2 Facilities in Refinery Plant

Briefly, oil and gas refinery plant consist of several production units which utilized to distillate crude oil into several beneficial products such as gasoline, jet fuel, bitumen and more (Chesnes, 2009). This project had analysed crude distillation unit, crude fractionation unit, catalytic reforming unit which from sweet crude refinery plant and two hydrotreater unit from lube oil plant where each unit has their own boundary. For further discussion, in Table 2.1 had elaborated further about general function of refinery processing unit which referred from Peiyang Chemical Eng. Co. (n.d.).

Table 2.1: Basic oil and gas refinery process unit

<table>
<tr><th>No.</th><th>Unit</th><th>Role</th><th>Plant classification</th></tr>
<tr><td>1.</td><td>Crude oil distillation unit</td><td>Refine and separate the crude oil into useful petroleum products by undergoing distillation process.</td><td rowspan="3">Sweet crude refinery plant</td></tr>
<tr><td>2.</td><td>Catalytic reforming unit</td><td>To increase the value of heavy naphtha by upgrading the naphtha to a component that can contribute increasing the octane number of motor gasoline (mogas) or called as reformate.</td></tr>
<tr><td>3.</td><td>Crude fractionation unit</td><td>To further fractionate the feed into lube distillates which referred on the required boiling point and viscosity. This process performed at a pressure well below atmospheric pressure.</td></tr>
<tr><td>4.</td><td>Hydrotreater unit</td><td>To re-arrange the hydrocarbon molecules in-order to produce lube base oil which referred to certain specifications such as viscosity index, pour point and noack volatility.</td><td>Lube oil plant</td></tr>
</table>

It is important for the researcher to identify the boundary for each unit because the researcher will further classify failure cause of each production unit into three types of failure causes which are internal unit failure, external unit failure and external plant failure. Internal unit failure means that a failure occurs inside or within the boundary of the production unit. Basically, it occurs due to internal equipment, operator's error, process upset and internal inventory management. Next, external unit failure means a failure occurs outside boundary of the production unit. For example, the catalytic reforming unit need to stop the production (actual throughput < 90% of planned throughput) because of failure occurs outside the region of catalytic reforming unit such as equipment in other production unit failures, switching mode, feedstock shortage, inventory management and process upset. Lastly, external plant failure means a failure occurs outside the boundary of refinery plant. In other words, the company does not have power to avoid the failure such as bad weather occurs and cause the crude shipment being delayed which known as logistic hiccup.

Furthermore, there are numerous of equipment being utilized in refinery plant such as mechanical rotating equipment, mechanical static equipment, electrical equipment and pipeline system (Telford, Mazhar, & Howard, 2011). However, this study focused on mechanical rotating and mechanical static only. For mechanical rotating equipment consists of pump, compressor and blower. Meanwhile, for mechanical static equipment consist of column, vessel, heat exchanger, reactor, furnace and air fan cooler. The equipment boundary had been referred from EN ISO 14224:2016 which had been attached at the appendix. The failure mode of the equipment which effected the performance of production unit had been analysed by the same data which sourced from Melaka refinery plant production unit failure data.

2.2 Failure Rate

General definition of failure is “an occurrence that happens when the delivered service gets out from correct service.” (Afsharnia, 2017). Meanwhile, a frequency of failure was called as failure rate. For this project, failure rate data for refinery production unit, equipment and component are the main input to undergo RBD and DES simulations. The reason is failure rate of a system reflected the reliability of the system. Reliability is a probability of a system to perform within a defined period with certain restrictions under certain condition where reliability also proportional expression of a system’s operational availability (Afsharnia, 2017). Therefore, the system’s reliability and availability can be predicted by analysing the recorded failure rates or failure intensity. There are several common basic categories of failure rates which can be classified as repairable and non-repairable system.

2.2.1. Repairable System

For this project, repairable system is referred to refinery production unit and equipment which been labelled as ‘as bad as old’. Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR) are the common parameters of failure rate being used for repairable system (Afsharnia, 2017). As been reported from ReliaSoft Corporation (2015, May 22), “MTBF can be expressed as the time passed before a component, assembly or system break down under the condition of a constant failure rate.”. Besides that, it is commonly used in RAM study analysis to predict the performance of equipment in future. MTBF can be calculated by using equation (1) and failure rate can be calculated by using equation (2):

$$MTBF = \frac{T}{n} \quad \text{Equation (1)}$$

T = Total time

n = Number of failures

$$\lambda = \frac{1}{MTBF} \quad \text{Equation (2)}$$

λ = failure rate

Meanwhile, MTTR can be described as an average total time spent to perform unscheduled corrective or preventive maintenance divided by the total of repair numbers (ReliaSoft Corporation, 2015, May 22). According to Afsharnia (2017) MTTR is the anticipated time period which started from a failure occurs to the repair of maintenance fulfilment which applicable for repairable system only. However, the MTTR and MTBF are applicable for the system which has constant failure rate. Thus, for the system which not having constant failure rate it must perform the life distribution to get more precise simulation result.

For this project cases, the unit level of simulation model did not use MTTR and MTBF as failure rate parameters because it has used life distribution parameters which being performed using Weibull distribution. Nevertheless, the equipment level of simulation had used MTTR and MTBF as failure parameters because it cannot perform equipment's life distribution in Weibull distribution due to low number of failure occur (less than 5 failures occured).

2.2.2. Non-Repairable System

Non-repairable system is a system which labelled as 'as good as new' and for this project it had referred to the equipment's failure modes. Generally, non-repairable system used Mean Time To Fail (MTTF) to measure it's life time because this statistical value is defined as the average time expected until the first failure of a component (Afsharnia, 2017).

2.2.3. Types Failure Phase

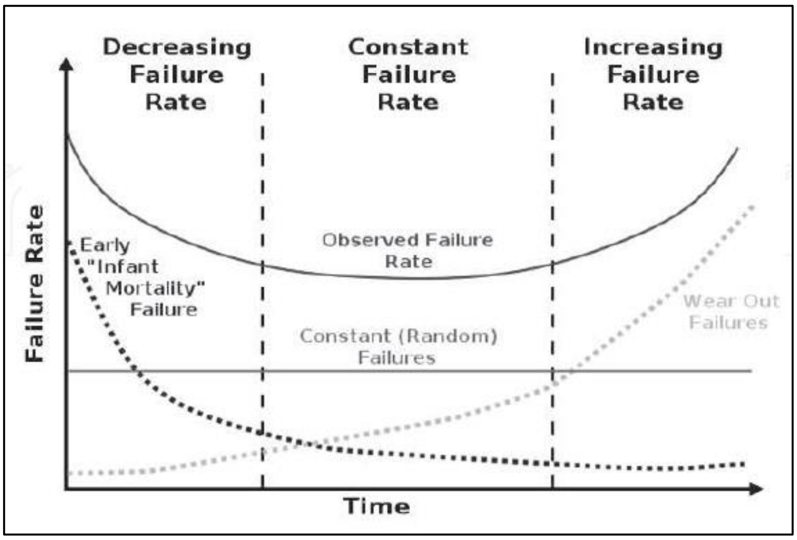

Figure 2.2: Common bathtub curve for a machine

According to (Freeman, 1996), there are three types of failure phase which referred to the bathtub curve in Figure 2.2. The three types of failure phases are early life period, useful life period and wear out life period. In early life period, the system is having high failure rate and exhibit a decreasing failure rate which the contribution of the high failure maybe due to incorrect installation and poor design. However, as the system reached useful period of life, the failure rate will be stabilized to an approximately constant rate of failure. Lastly, when the system reached wear out life period, the failure rate increases because due to fatigue and degradation.

2.2.4. Life Distributions

The collected production unit failure rate data will be used to construct life distributions for refinery plant production unit, equipment and component. Based on ReliaSoft Corporation (2015, May 22), the term life distribution is to describe the collection of statistical probability distribution which used in RAM study analysis. A statistical distribution is describing a probability density function (pdf) where it has been formulated by previous engineers and mathematicians which being developed certain behaviour into mathematically model by referring to the past data. Moreover, the statistical distribution is very useful for the researcher to study and analyse the future life time of a system.

ReliaSoft Corporation (2015, May 22) had stated that there are many types of life distribution curves which represent the behaviour of a system such as Exponential Distribution, Weibull Distribution, Lognormal Distribution and Normal Distribution. Nonetheless, this project only used three types of distribution only which are Exponential Distribution, Weibull Distribution and Lognormal Distribution.

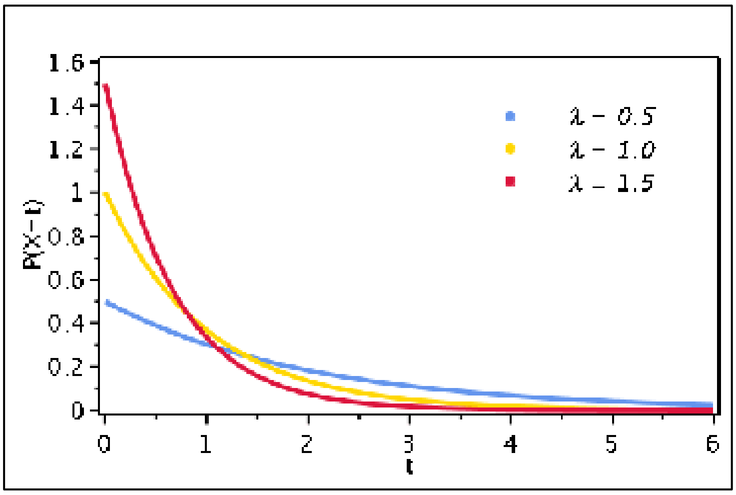

Figure 2.3: Example of common Exponential distribution.

Figure 2.3 had illustrated an example of the Exponential Distribution curve. It is commonly used for a system which exhibiting a constant failure rate. In this project, this type of life distribution has been applied for the equipment and failure mode because the failure data is too little to be plotted using Weibull Distribution. There are two types of Exponential Distribution which are 2-parameter and 1-parameter. The simulation had used 1-parameter of Exponential Distribution where the required parameter is failure rate, λ. The formula to calculate probability density function (pdf) of 2-parameter and 1-parameter of exponential distribution are in equation (3) and (4).

$$f(t) = \lambda e^{-\lambda(t-\gamma)}$$ Equation (3)

$$f(t) = \lambda e^{-\lambda t}$$ Equation (4)

λ = constant failure rate

γ = location parameter

Assumed that:

$\gamma = 0$

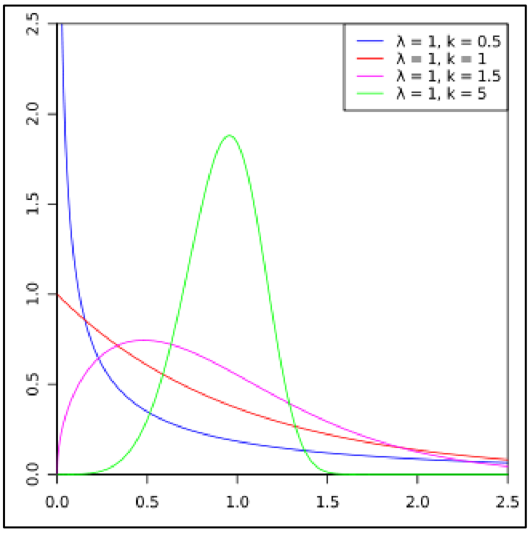

Figure 2.4: Example of common Weibull distribution

In Figure 2.4 had displayed some examples of Weibull distribution graph. This distribution commonly used in reliability study where it used to model material strength, times-to-failure of a system. Thus, it was being applied to production unit life distribution. Same as Exponential Distribution, it has two types of distribution which are 3-parameter Weibull Distribution and 2-parameter Weibull Distribution. Formula of pdf for both was written in equation (5) and (6) respectively. This project had used 2-parameter Weibull Distribution. Thus, the required parameter from the life distribution are scale parameter, η and shape parameter, ß.

$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-(\frac{t-\gamma}{\eta})^{\beta}}$$ Equation (5)

$$f(t) = \frac{\beta}{\eta}(\frac{t}{\eta})^{\beta-1} e^{-(\frac{t}{\eta})^{\beta}}$$ Equation (6)

η = scale parameter

ß = shape parameter

γ = location parameter

Assumed that location parameter,

$\gamma = 0$

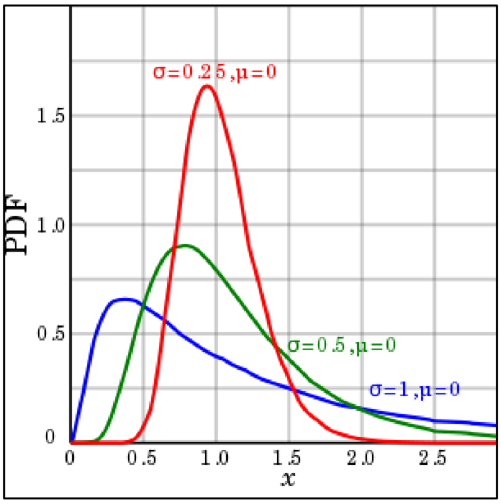

Figure 2.5: Lognormal distribution

In Figure 2.5 had illustrated an example of Lognormal Distribution which commonly used for system's downtime. Thus, this type of distribution had been applied for downtime of production unit where it could identify the log mean and log standard deviation of repair time. The formula for pdf of Lognormal Distribution is being stated in equation (7).

$$f(t) = \frac{1}{t\sigma'\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t'-\mu'}{\sigma'}\right)^2}$$

$$f(t) \geq 0, t > 0, \sigma' > 0$$

$$t' = \ln(t) \qquad \text{Equation (7)}$$

μ' = mean of the natural logarithms of the times-to-failure

σ' = standard deviation of the natural logarithms of the times to failure.

2.3 RAM Study

RAM study refers to Reliability, Availability and Maintainability study. Barberá, *et al* (2012) had defined reliability, maintainability and availability where they defined reliability as a probability that the item will perform its required function under given conditions for the time interval. Next, they defined maintainability as how long the time taken to repair the system which determines the downtime patterns. Lastly, they had defined availability as a percentage of uptime over the time horizon where it is determined by reliability and maintainability.

Corvaro, *et al*, 2017 had proved that RAM study is an engineering tool which has an ability to evaluate the system performance at different stages in design process where it can be used to improve the availability of reciprocating compressor. The availability of the system can be improved by enhancing reliability and maintainability. The reliability can be enhanced by prolonging the life time of the system. For example, perform proactive and preventive maintenance periodically especially for critical equipment. Next, the maintainability can be improved by reducing the downtime of the system. For example, prepare a sufficient amount of spare parts for critical equipment. The downtime and uptime for the system can be illustrated like in Figure 2.6 where the TTF is Time To Failure and TTR is Time To Repair

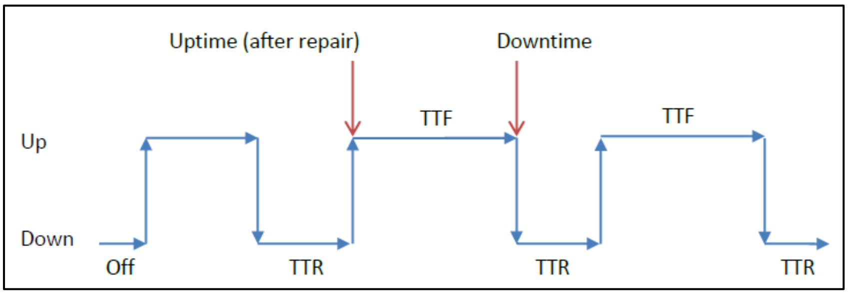

Figure 2.6: Uptime and Downtime of a system

After extensively doing research about RAM study, there are several advantages for selecting RAM study as a tool to assess oil and gas refinery's plant utilization. First, RAM study has an ability to identify weak points with respect to failure and repair time that affected plant availability which lead to make effective solutions and actions to enhance plant availability. The point has been proved by Barabady & Kumar (2008) where they had implemented reliability analysis in-order to assess the performance of mining machines in Iran. The analysis had helped the, to identify critical components which to failure of the machines. Second, RAM study also can estimate plant availability and assess various alternative quantitatively for improving plant availability such as spare part allocation policy, maintenance strategy and manpower strategy. Herder, Luijk, and Bruijnooge (2008) had promoted that the RAM analysis is a valuable tool because based on their investigation, the enhancement of plant's reliability could lead to reducing maintenance and manpower costs for Lexan Plant at GE Industrial, Plastics. Third, RAM study provides a decision tool for management to effectively align operational decisions with organization's objective such as to decide how much should the company invest for the critical equipment for improvement strategy. Kumar, Chattopadhyay, & Kumar (2007) had improved the maintenance practice according to company objectives for internal grinding machine in India. They had integrated between reliability theory, economic analysis and technological decisions based on design changes of existing equipment.

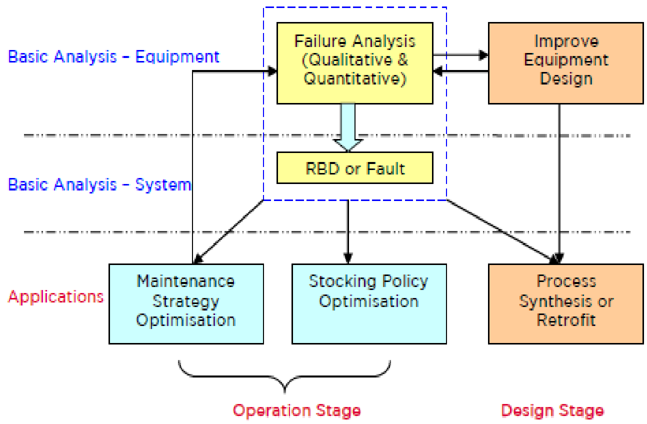

Figure 2.7: RAM analysis cycle

Figure 2.7 had illustrated basic RAM analysis cycle which being practiced by most of reliability engineers. The applications or recommendation actions can be implemented after doing a system basic analysis. For this project, RBD and DES simulation models had been utilized as system basic analysis. Hence, the recommendation actions will be implemented according to the results from the simulation models.

2.4 Reliability Block Diagram

Based on current research, there are many types of RAM simulation model has been developed in industry such as Markov chain, Petri-Net and Reliability Block Diagram (RBD) (Barberá, *et al*, 2012). RBD simulation model has been selected in order to assess the plant utilization of refinery because this tool has an ability to quantify the availability of production unit, equipment and component. According to Catelani, *et al*, (2019), RBD is a combination of components functional diagrams which simulated to assess and predict the availability of the system. In other words, RBD being used to represent the logic relationship between components and system failures. The RBD used failure distribution data as the input of the model (Proaimltd, n.d.). Moreover, there are three main types of RBD configurations which are series configuration, parallel configuration and k-out-of-n parallel configuration which based on ReliaSoft Corporation (2015, May 5).

2.4.1. Series Configuration

Figure 2.8: Series configuration.

Generally, a failure of any component in series configuration will result a failure for the entire system which shown in Figure 2.8. Thus, all components required to success in-order to make sure the system is success. Usually, the components connected in series configuration are the components that seldomly occur a failure such as mechanical static equipment. In RAM study case, the component with the least reliability has the biggest impact on the system reliability. Hence, the reliability of the series configuration system is always less than the reliability of the least reliable component. Moreover, the number of components connected in series system is another concern need to be notified because as the number of components connected in series increases, the reliability of the system decreases.

2.4.2. Parallel Configuration

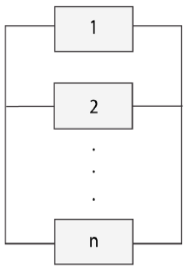

Figure 2.9: Parallel configuration.

Figure 2.9 had displayed a parallel configuration system. In parallel configuration, the system will succeed if at least one of the components succeed. Thus, it also called as redundant units where it is one of important aspects of reliability because by adding redundancy, it can improve system's reliability. Usually, critical equipment in refinery plant will be connected in parallel such as heat exchanger.

2.4.3. K-out-of-N Parallel Configuration

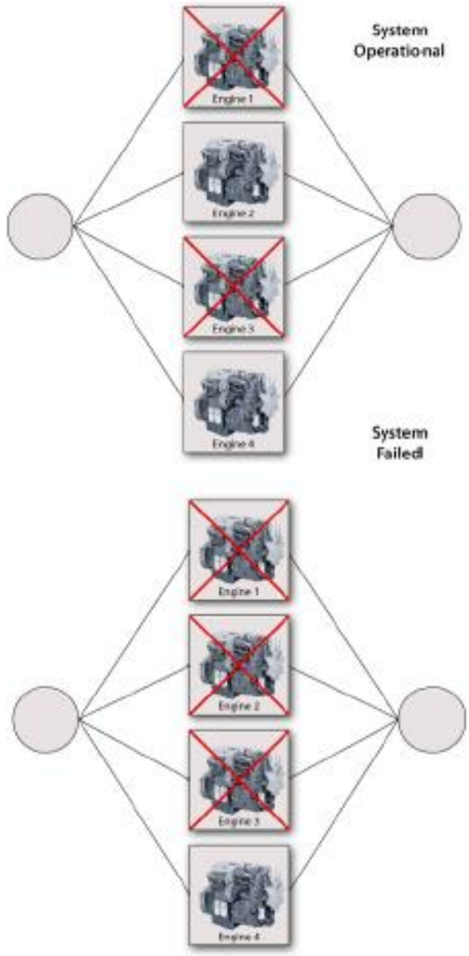

Figure 2.10: 2-out-of-4 parallel configuration

In Figure 2.10 had shown an example of 2 out of 4 parallel configuration. That means the system will succeed when at least 2 components succeed. Commonly, critical equipment which require standby will use this configuration such as rotating equipment. There are two cases need to be considered for this configuration. First, when the components are identical in terms of same failure distributions. Thus, the reliability of the system can be evaluated using binomial distribution. For second case, when the components are not identical where the failure distributions are not same. One of the methods is to use event space method.

2.5 Discrete Event Simulation (DES) Method

According to Sumari, *et al*, (2013), Discrete Event Simulation (DES) method is a method which shows the sequences of each event at a certain point of changes level that occur in the system in a discrete time. In other words, this simulation model method is depending with time which called as dynamic model. Meanwhile the RBD is a static model where it is time independent model. The main purpose for the researcher to utilize this method is because this simulation model was frequently used in production logistic where it could provide good support for optimization of the production logistic system (Wang & Chen, 2016). Kikolski (2016) had demonstrated that the bottleneck problem is one of the vital issues faced by production plant while finding solutions to optimize the production rate by using top down approach and stochastic method.

For this FYP case, this DES method can assess the plant utilization by focusing more on the throughput in refinery plant in-order to find the bottleneck of refinery production processes. However, by using DES method in assessing refinery plant is a new thing and there are limited amount of research was being conducted.

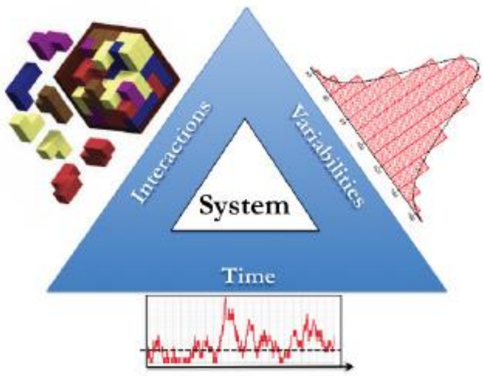

Figure 2.11: Main features of operational system

Since the DES method has a close relation with operational system, thus the researcher had identified three main features of operational system. Figure 2.11 had illustrated the three main features of operational system which retrieved from Beaverstock, Greenwood and Nordgren (2017). First feature is interaction which defined a system and encompass relationships among system resources for examples people, equipment and material. Next, second feature is variabilities. The variabilities consist of planned and unplanned event. Examples of planned variabilities are resources changing due to planned schedule, systematic variations in task time, etc. Meanwhile, generally the unplanned variabilities related with failures and absenteeism. Lastly, the third feature is the most complex feature to be studied which is time. (Wang & Chen, 2016) had argued that one of the main reasons for operational systems are so complex to be studied is because the system interactions and variabilities combined over time which lead to behaviour of system. Hence, it is important to capture a system over relevant period of time.

CHAPTER 3

METHODOLOGY

3.1 Project Assumptions

The following are several assumptions have been considered to simplify the project simulation:

1. Assumed there is no buffer tank in the simulation models.
2. Assumed all unit and equipment are repairable and have been set as minimal repair in the RBD modelling (as bad as old).
3. Minimum duration of repair time of failure (days) for production unit and equipment failed is 1 day.
4. For the equipment which has less than 5 number of failure will consider as constant failure rate.The downtime of an equipment is considered as Active Repair Time (ART).
5. The current behaviour of the production unit and equipment are same with the historical failure data was taken from 2012 until 2018.

3.2 Tools

Since this project will assess the refinery plant utilization by using simulation, there are several software had been utilized to execute this project:

3.2.1 Microsoft Excel

MS Excel had been used to collect and re-arrange data by classifying downtime and uptime of the unit. Next, MS Excel also been used to construct TBF table for production unit, equipment and failure mode. Then, from the TBF table the researcher can calculate the duration of uptime and downtime chronologically and calculate the cumulative uptime and downtime. Lastly, the verification process also had been conducted using MS Excel where the theoretical availability has been compared by simulated availability.

3.2.2 Reliasoft Weibull++

Weibull++ had been utilized to analyse the life distribution parameters of each production unit. This reliability software capable to construct life distribution of the production unit based on the arranged data from MS Excel. Besides that, it been used to estimated next time of unit failure.

3.2.3 Reliasoft BlockSim

The simulation model was built in this software because the parameters from Weibull++ had been key-in into the simulation blocks. Then, the BlockSim can estimate the system availability by connecting the sub-systems into Reliability Block Diagram (RBD). The production loss also has been included in the simulation in-order to estimated how much production loss due to the equipment failure.

3.2.4 FlexSim FloWorks

FlexSim FloWorks will conduct DES model where the main objective of this simulation is to assess the throughput from the crude distillation unit. The equipment in the simulation will use the parameters from the Weibull++. By using this software, the researcher could analyse the bottleneck of the production unit.

3.3 Project Flow Chart

The constructed flow chart in Figure 3.1(a) and Figure 3.1(b) are the project flow chart which referred from Corvaro, Giacchetta, Marchetti & Recanati (2017). However, the researcher had done some innovations in the flow chart where the researcher had segregated the flow chart into four main sections which are data input, exploratory analysis, modelling and results. First section, data input is very important where the data collection will decide the simulations will get the correct results or not. Thus, it is significant for the researcher to validate the data collection with experts before process to the next steps. Second section, exploratory analysis is where the researcher starts to re-arrange the failure data in-order to find the Time Between Failure (TBF) and Time To Repair (TTR)."

Next, in modelling section the researcher starts to fit the failure data into life distribution by using Weibull++. Other than that, RBD modelling also starts being constructed for refinery production unit, equipment and component. In addition, the DES modelling also will be constructed simultaneously with RBD modelling in-order to reduce time consumption. All functional diagrams have been referred to Process Flow Diagram (PFD) and Pipeline and Instrumentation Diagram (P&ID). Lastly, in results section the researcher will analyse and interpret the results from the simulations. By interpreting the results, the researcher could come out with recommendation action for refinery improvement strategies.

For RBD simulation, the flow chart will be repeated three times to execute the simulations for refinery production unit level, equipment level and component level. Meanwhile, DES method will not repeat the flow chart because the discrete event simulation will focus on crude distillation unit only.

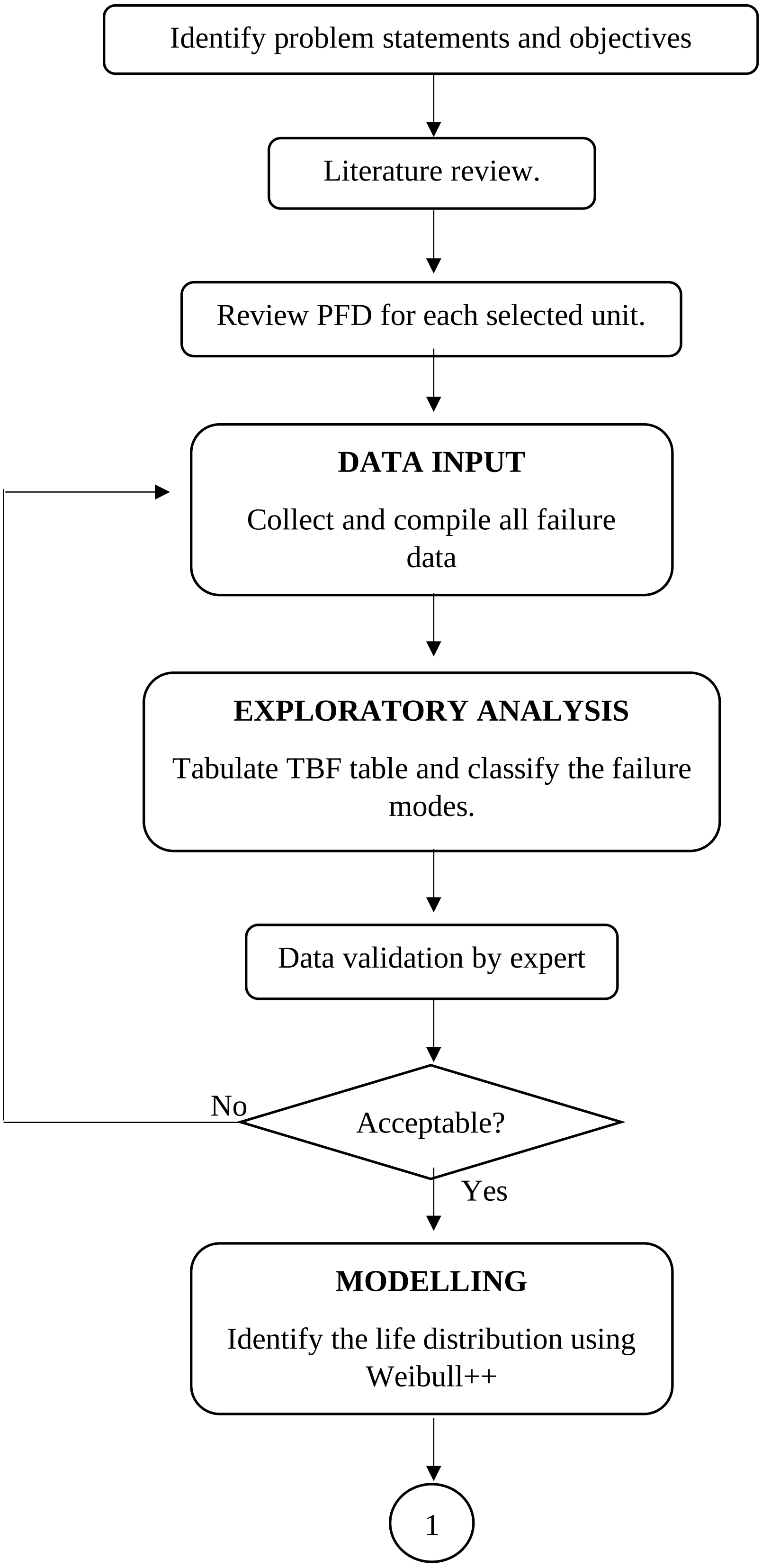

Figure 3.1(a): Project flow chart

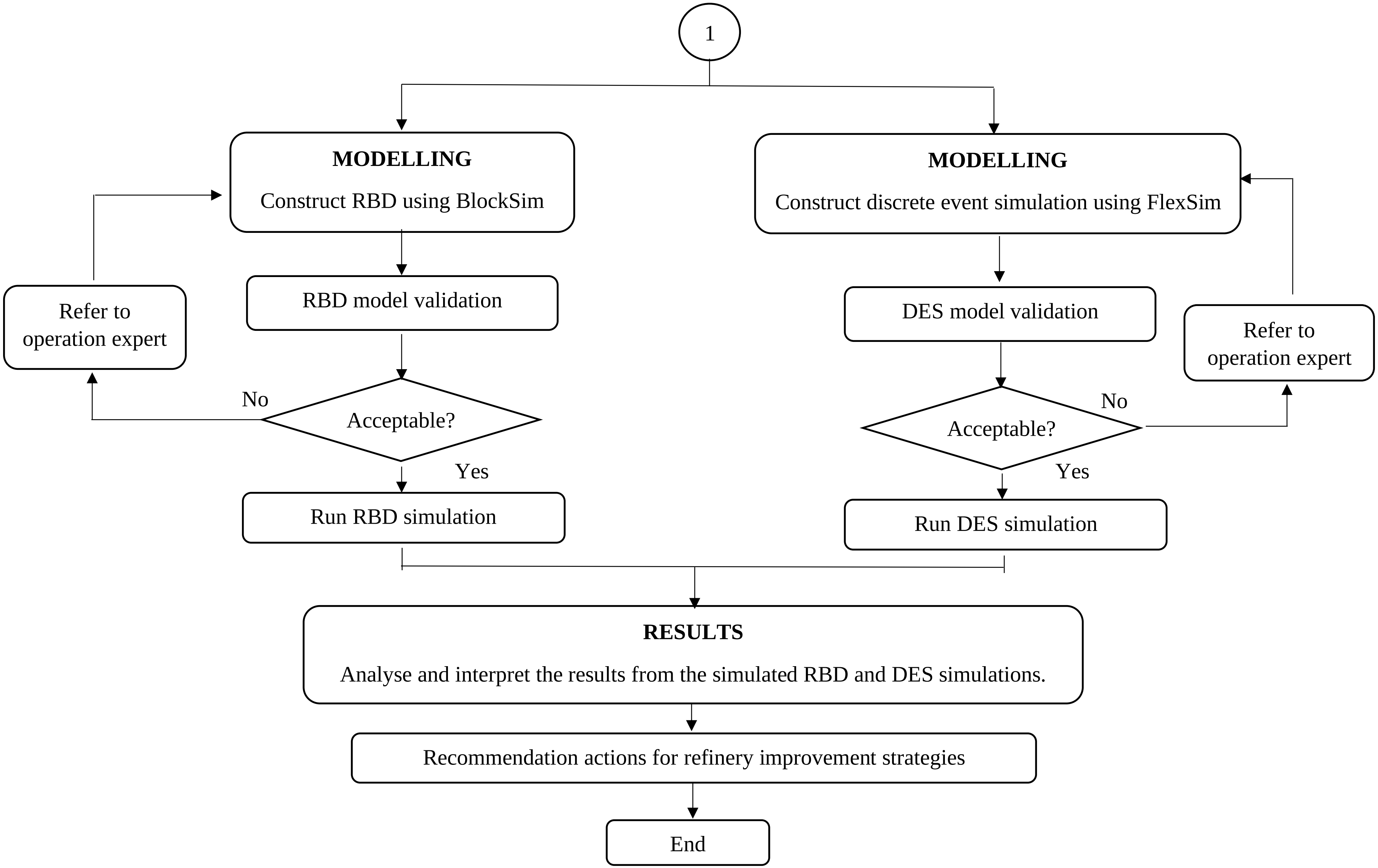

Figure 3.1(b): Project flow chart

3.4 Project Gantt Chart

In Figure 3.2(a), (b), (c), (d) and (e) had displayed the FYP1 and FYP2 Gantt chart. Based on this chart, there are seven sections which are project planning, data collection, data compilation, data analysis, results, project verification and project documentation.

Final Year Project Gantt Chart																														
TASKS	FYP-1														BREAK		FYP-2													
	Sep-19				Oct-19				Nov-19				Dec-19				Jan-20				Feb-20				Mar-20					Apr-20
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14			W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1. Project briefing and planning																														
1.1 Discussion about project objective and background study.																														
1.2 Plan the flow of project.																														
1.3 Decide the workscope of project.																														
2. Data collection																														
2.1 Unit performance data. (SPDE & RSM)																														
2.2 Equipment perfromance data for critical equipment.																														
2.3 Process Flow Drawing (PFD) for critical unit.																														
2.4 Throughput weightage in critical unit.																														
2.5 Percentage the produced petroleum products.																														
2.6 Schedule of crude arrival.																														

Figure 3.2(a): Gantt chart for project planning and data collection

Final Year Project Gantt Chart																														
TASKS	FYP-1														BREAK		FYP-2													
	Sep-19				Oct-19				Nov-19				Dec-19				Jan-20				Feb-20				Mar-20					Apr-20
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14			W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
3. Data arrangement and compilation																														
3.1 Compile the unit performance data in one excel file.		■	■	■																										
3.2 Classify the Uptime and Repair Time of units for each day based on project's failure definition.			■	■																										
3.3 Construct the Time Between Failure (TBF) table for each selected unit.				■	■																									
3.4 Identify the functional location for each main equipment in critical unit.					■																									
3.5 Construct TBF table for all equipment in critical unit.						■	■	■																						
3.6 Classify the failure mode of critical unit and critical equipment.								■	■	■																				

Figure 3.2(b): Gantt chart for data arrangement and data compilation

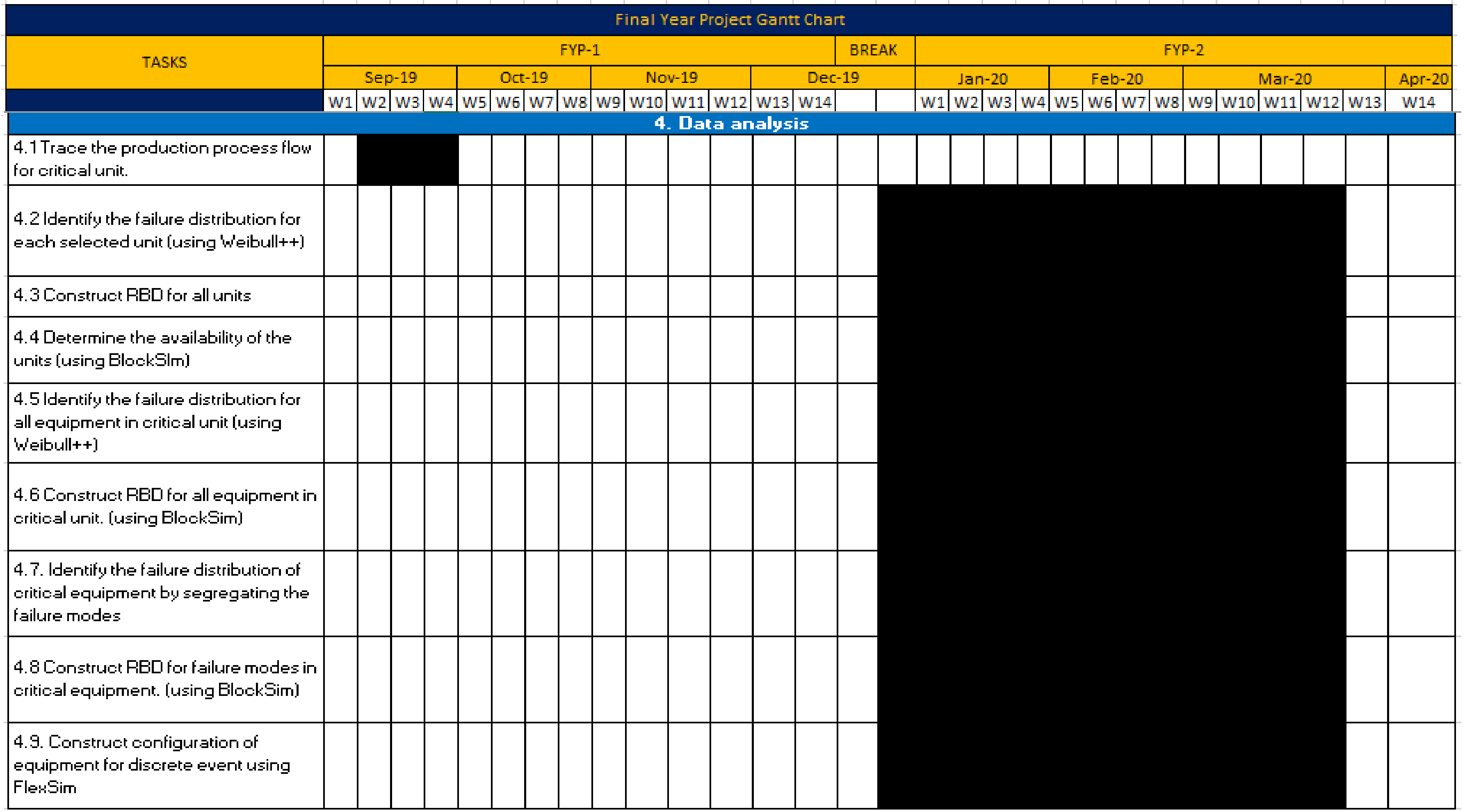

Figure 3.2(c): Gantt chart for data analysis

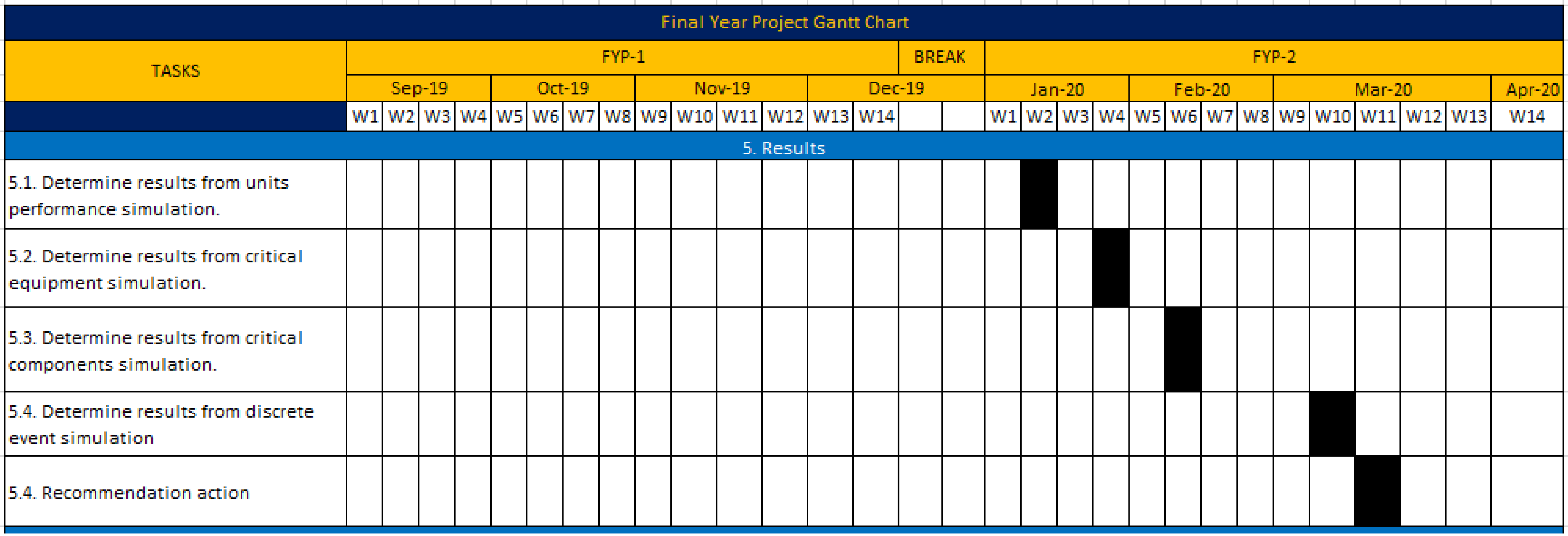

Figure 3.2(d): Gantt chart for results

Final Year Project Gantt Chart																														
TASKS	FYP-1														BREAK		FYP-2													
	Sep-19				Oct-19				Nov-19				Dec-19				Jan-20				Feb-20				Mar-20					Apr-20
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14			W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
6. Project verification																														
6.1. Verificatio of collected data.		■																												
6.2. Verification of TBF tables.					■			■																						
6.3. Verification of failure distribution using Weibull++ software.																		■	■			■								
6.4. Verification of constructed RBD in BlockSim software.																		■	■			■								
6.5. Verification of discrete event simulation.																										■				
7. Documentation																														
7.1 Proposal Defence presentation								■																						
7.2. Interim Report Submission														■																
7.3. Progress Report submission																							■							
7.4. Technical Paper																									■					
7.5. Viva presentation																											■			
7.6. Dissertation submission																												■		

Figure 3.2(e): Gantt chart for project verification and documentation.

3.5 Project Milestone

In Figure 3.3(a) had shown the FYP-1 planning and milestone where the researcher had followed the milestone while completing FYP-1 tasks.

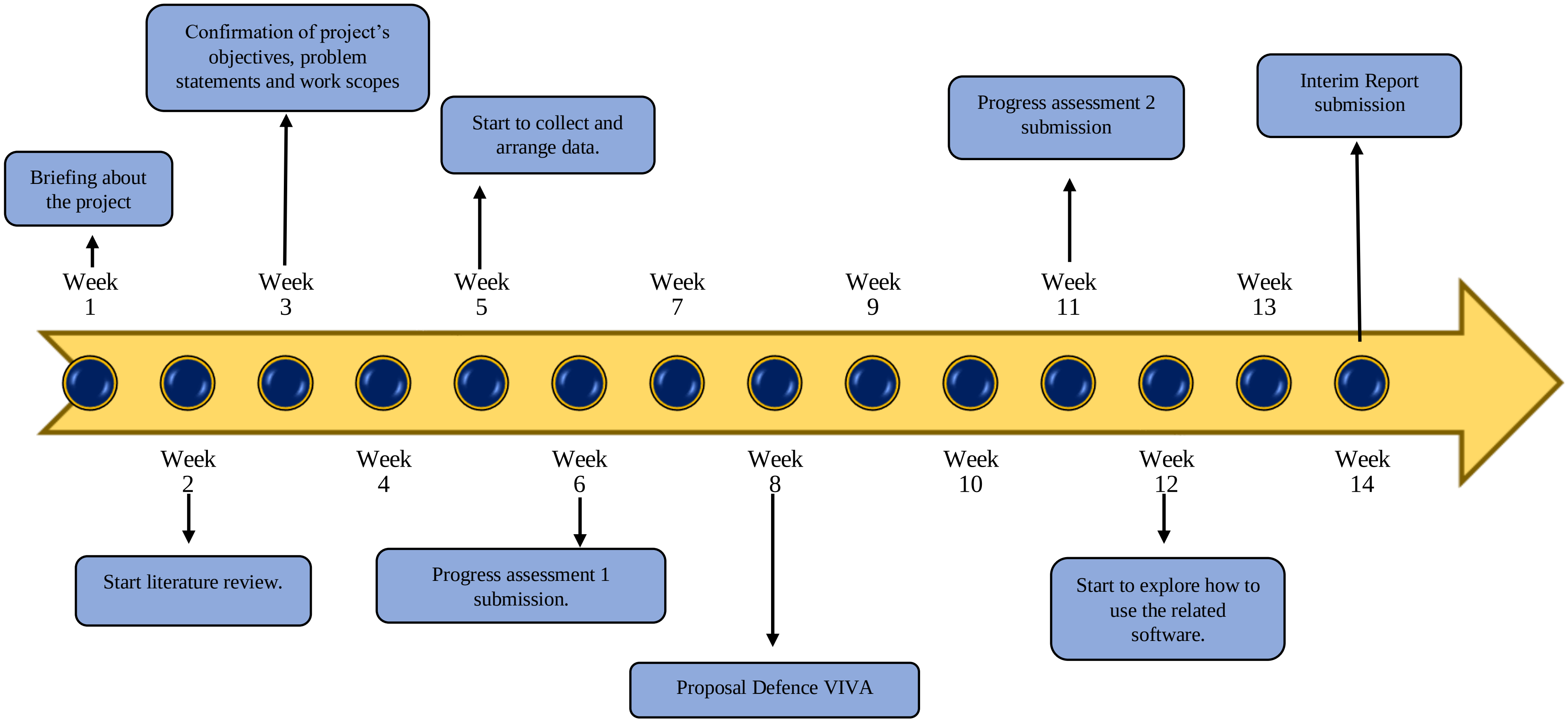

Figure 3.3(a): FYP 1 Planning and Milestone

In Figure 3.3(b) had shown the FYP-2 planning and milestone where the researcher will follow this project milestone to accomplish the FYP-2 tasks.

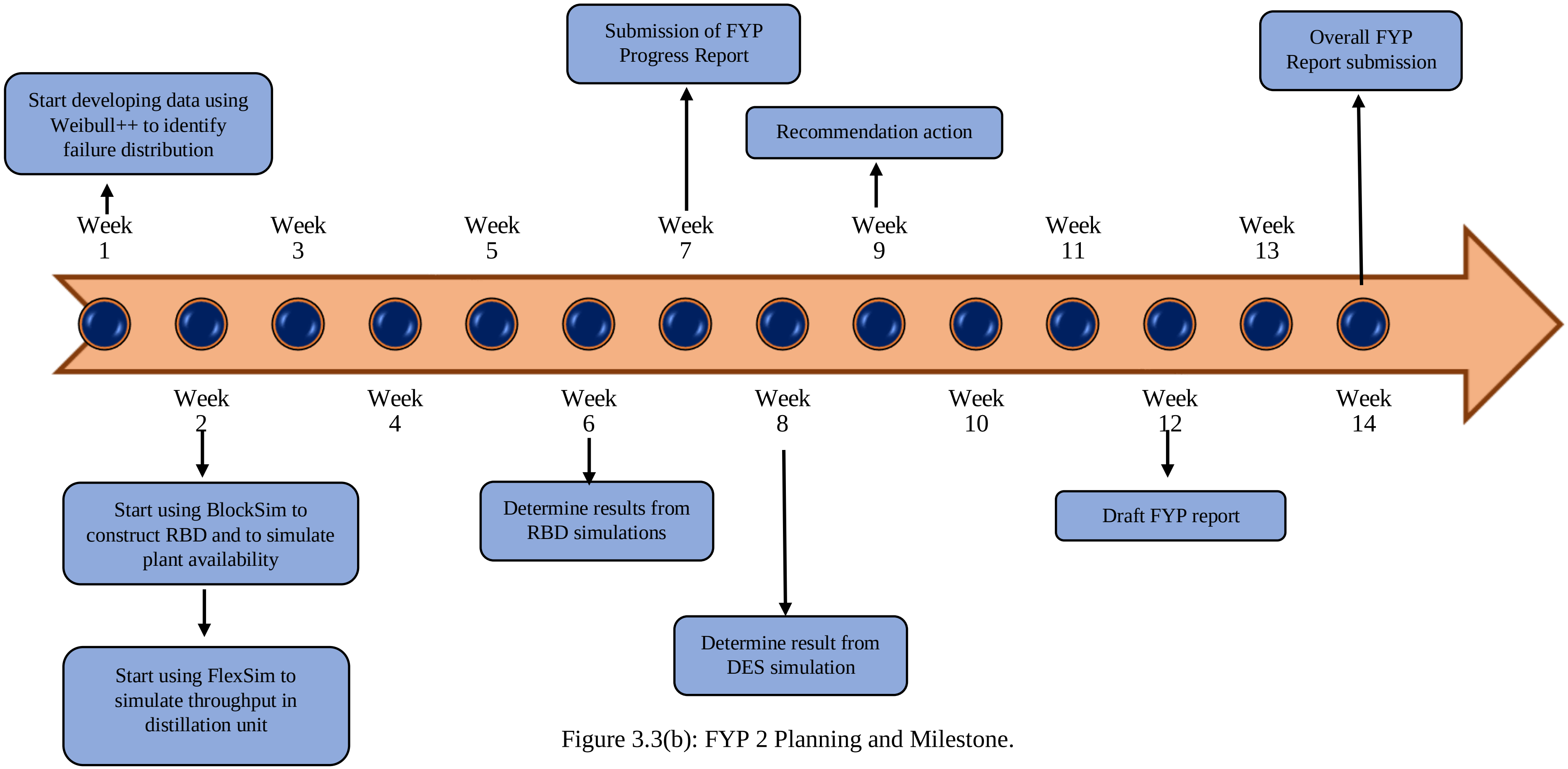

Figure 3.3(b): FYP 2 Planning and Milestone.

CHAPTER 4

RESULTS AND DISCUSSION

RBD simulation for production unit and equipment in refinery plant had been carried out. The results will be displayed in this section and the discussion of the results will be explain further in discussion section. The RBD simulation had used production unit performance data which taken from Melaka refinery since 2012 until 2018. List of production unit and the labelling used in RBD simulation had been shown in Table 4.1. There are five production units had been carried out for RBD simulation where three from sweet crude refinery plant and two from lube oil plant.

Table 4.1: Production unit labelled in RBD simulation.

Plant classification	Production unit	Labelled in RBD simulation
Sweet crude refinery plant	Crude oil distillation unit	CDU-1
	Crude fractionation unit	CFU
	Crude reformate unit	CRU-1
Lube oil plant	Hydrotreater unit	U-18, U-19

The RBD simulation result had used two types of metrics to measure the failure contribution of the simulation components which are Failure Criticality Index (FCI) and Downtime Criticality Index (DTCI). These metrics are being applied by ReliaSoft BlockSim to indicate the failure contribution in a system. According to ReliaSoft Corporation. (2015, May 5), "FCI is a relative index showing the percentage of times that a failure of the component caused a system failure." and the reference added the definition of DTCI which is "DTCI for the block is a relative index showing the contribution of the block to the system's downtime (i.e., the system downtime caused by the block divided by the total system downtime).".

For unit level, there will be three types of unit failure causes and each of the failure causes will be measured using FCI metric. Next, for equipment level the top 10 critical equipment will be ranked the failure contribution according to FCI and DTCI metrics.

4.1 RBD Simulation Results – Unit Level

4.1.1 Sweet Crude Refinery Plant

In Figure 4.1 had displayed a result from RBD where it indicates the percentage of production unit availability in sweet crude refinery plant. Based on the RBD simulation result, it is clearly illustrated that the production unit which has the lowest unit availability is CDU-1 (92.34%) which followed by CRU-1 (93.41%) and CFU (94.44%). The RBD configuration for each unit had been attached in appendix 1, appendix 2 and appendix 3.

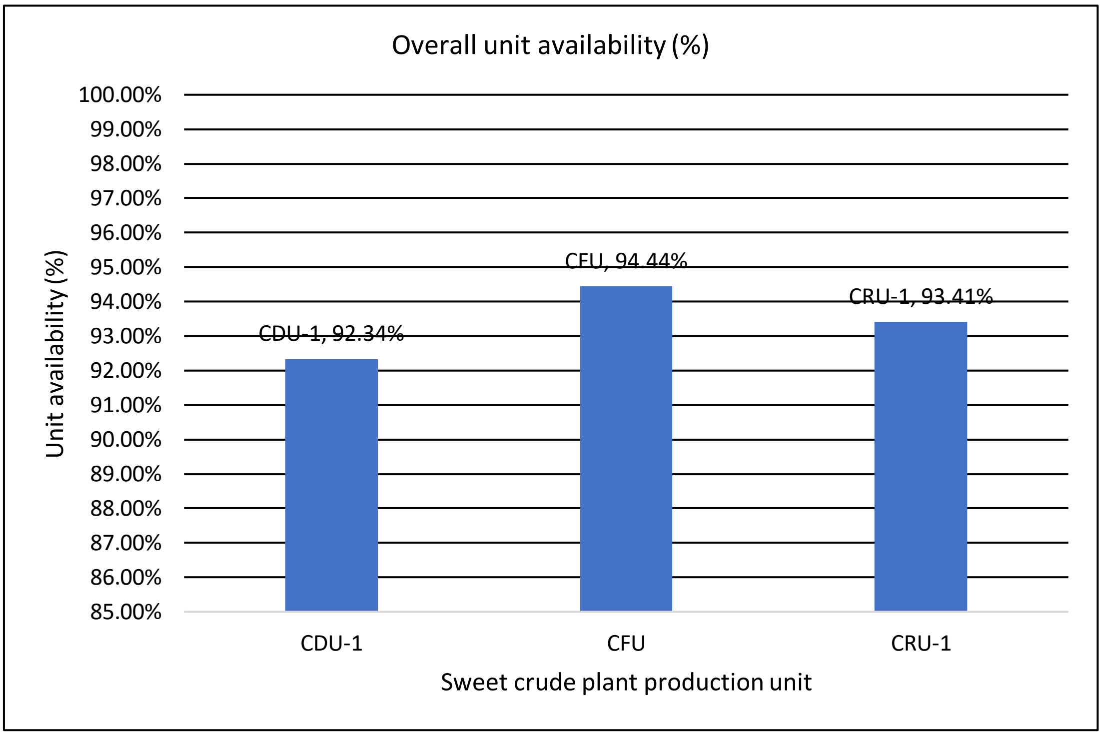

Figure 4.1: Overall unit availability for sweet crude refinery plant.

The RBD simulation had used life distribution parameters to reflect the behaviour of the production unit which being executed using Weibull++ software. In table 4.2 had tabulated the life distribution parameters and downtime distribution parameters for the sweet crude plant production units. In addition, Weibull++ software also had plotted a linearized probability of failure graphs for each unit in sweet crude plant where it had been attached in appendix 6, appendix 7 and appendix 8. The graphs are beneficial to estimated when is the next time of failure for the units with 95% of confidence level.

Table 4.2: Distribution parameters for production units in sweet crude plant

Unit	Life distribution parameters	Downtime distribution parameters	Estimated next time of failure (CL: 95%)	Unit availability (%)
CDU-1	ß = 1.3195 η = 88.4451 days λ = 0.0027 failure/day no. of failures = 76	μ' = 0.6318 day σ' = 0.5620	105 - 476 days of continuous operation	92.34%
CFU	ß = 0.9526 η = 35.9089 days λ = 0.033 failure/day no. of failures = 55	μ' = 0.6822 day σ' = 0.6354	161 - 821 days of continuous operation	94.44%
CRU-1	ß = 0.9386 η = 38.27 days λ = 0.03151 failure/day no. of failures = 50	μ' = 0.9448 day σ' = 0.7329	163 - 857 days of continuous operation	93.41%

The unit failure contribution for the production units had been segregated into three types of failure causes which are internal, external unit and external plant cause of failures. This initiative is to further analyse the root cause of production unit in sweet crude plant. In Figure 4.2 illustrated that each unit failure causes had been

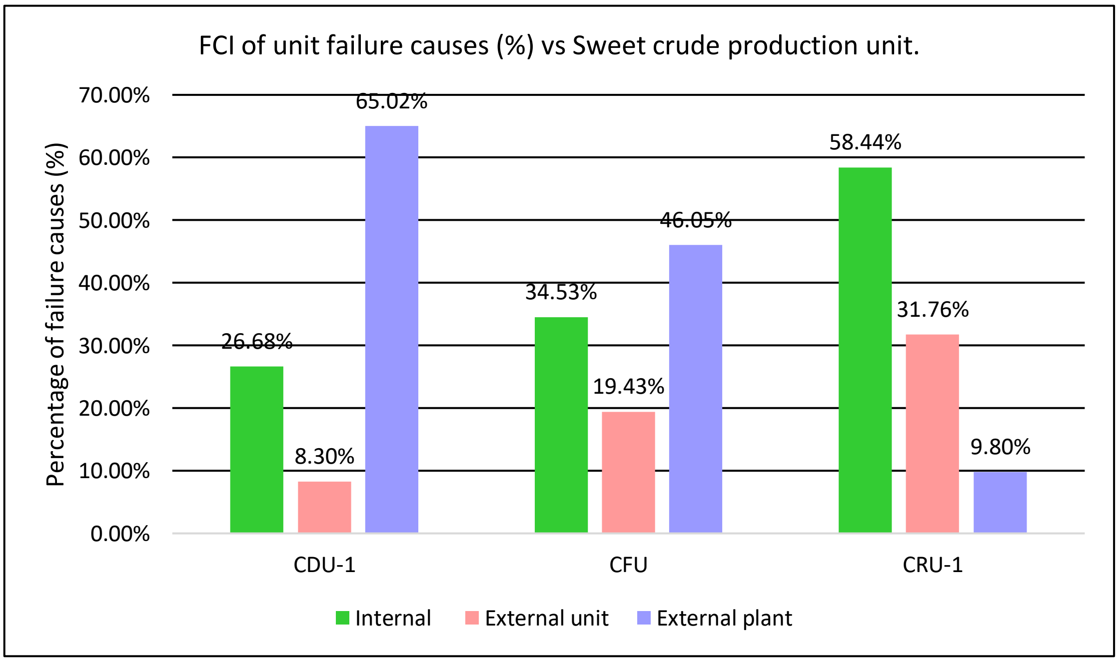

Figure 4.2: Percentage of failure causes contributed to unit failure in sweet crude plant

measured by using FCI metric to indicate the percentage of failure contribution to the unit failure.

Main contributors for CDU-1 failure is external plant failure cause. In other words, the performance inside the boundary of CDU-1 such as equipment, operators, process, etc in CDU-1 is good but the unplanned shutdown and slowdown occurred due to logistic hiccup, crude quality issue, inventory management etc which is beyond company's power to avoid the issues. Same result for CFU where the main contributor for unit failure is external plant cause of failure. Nevertheless, different situation for CRU-1 because the main contributors for unit failure is internal failure cause. This result indicates that mostly failure occur in CRU-1 perhaps due to internal equipment failure, operator error, process upset, etc. Thus, further analysis regarding the internal failure causes in CRU-1 need to be carried out where the analysis could lead to enhance the performance of sweet crude plant. In addition, the company could reduce the cost for unplanned corrective maintenance and maximize profit by prolong the equipment life and reduce time to repair.

Among these three failure causes, internal failure cause is the most straightforward for the operation and maintenance team to do the improvement strategy because it still within control by each production unit area. Thus, the internal cause of failure had been further classified into smaller category of failure in order to determine the bad actor of the production unit.

4.1.2 Lube Oil Plant

In Figure 4.3 had displayed a result from RBD where it indicates the percentage of production unit availability in lube oil plant. Based on the RBD simulation result, it is clearly illustrated U-19 had lower production unit availability than U-18. The RBD configuration for each unit had been attached in appendix 4 and appendix 5.

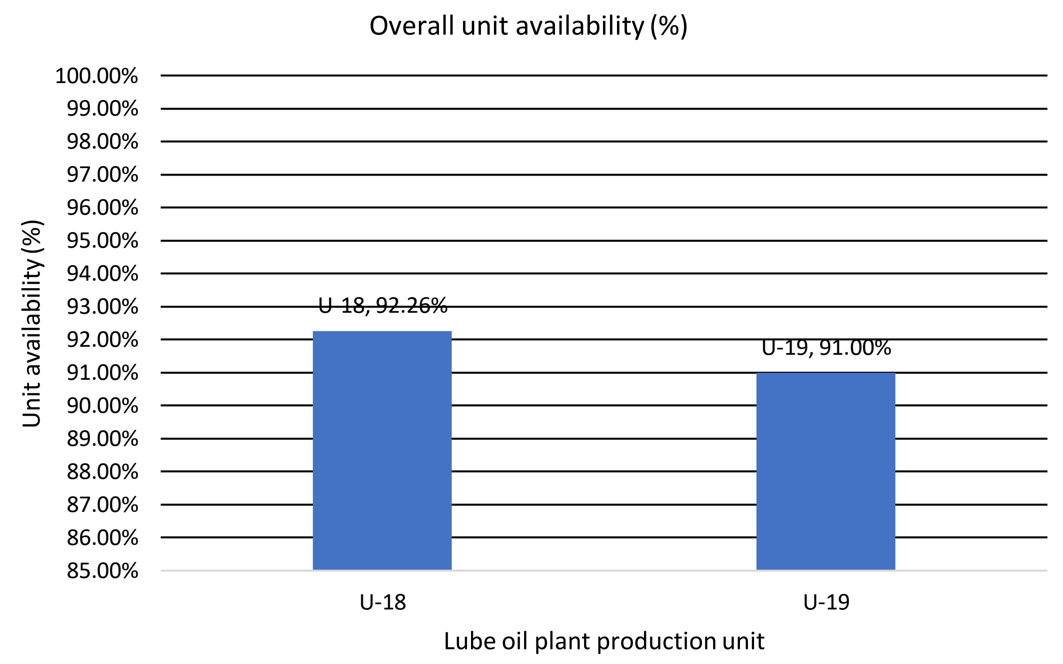

Figure 4.3: Overall unit availability for lube oil plant

Same as sweet crude refinery plant simulation model, the RBD simulation had used life distribution parameters to reflect the behaviour of the production unit which being executed using Weibull++ software. In table 4.3 had tabulated the life distribution parameters and downtime distribution parameters for the lube oil plant production units. Furthermore, Weibull++ software also had plotted a linearized probability of failure graphs for each unit in lube oil plant where it had been attached in appendix 9 and appendix 10. The graphs are beneficial to estimated when is the next time of failure for the units with 95% of confidence level.

Table 4.3: Distribution parameters for production units in lube oil plant

Unit	Life distribution parameters	Downtime distribution parameters	Estimated next time of failure (CL: 95%)	Unit availability (%)
U-18	ß = 0.9942 η = 51.67 days λ = 0.0198 failure per day	μ’ = 1.0385 day σ' = 0.9578	251 – 1011 days of continuous operation.	92.26 %
U-19	ß = 0.7351 η = 3.66 days λ = 0.3853 failure per day	μ’ = 0.5753 day σ' = 0.6521	29 – 512 days of continuous operation.	91.00 %

The unit failure contribution for the production unit in lube oil plant had been segregated into three failure causes (same as in sweet crude refinery plant) which are internal failure cause, external unit and external plant. In Figure 4.4 illustrated that each unit failure causes had been measured by using FCI metric to indicate the percentage of failure contribution to the unit failure. According to the result, main contributors for U-18 and U-19 failure are external unit failure cause. Based on the investigation, the external unit cause of failure is mostly due to unit switching mode, power issue, crude quality issue and inventory issue.

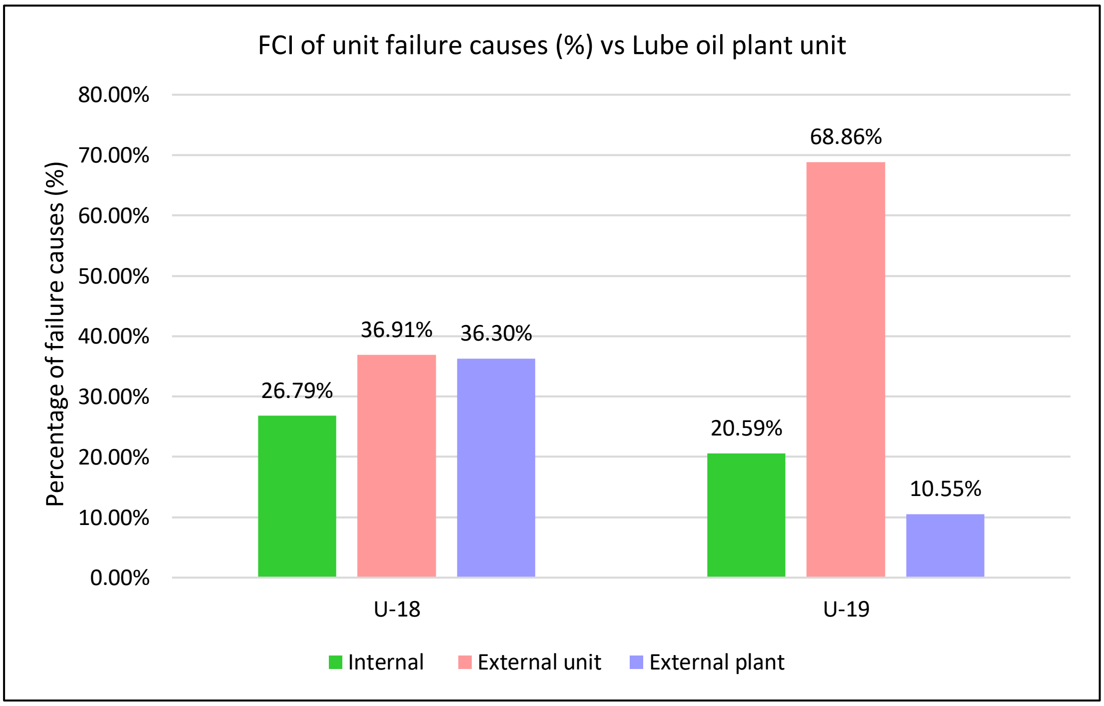

Figure 4.4: Percentage of failure causes contributed to unit failure in lube oil plant

4.1.3 Ranking of Internal Failure Contribution (%) Based on FCI

Based on the project objectives, the simulation model must analyse critical equipment quantitatively for critical unit. Critical unit here means that the production unit has the highest percentage of equipment failure contribution which effected the unit to have unplanned shutdown and slowdown. Therefore, in this section will rank which production unit has the highest equipment failure contribution among sweet crude plant lube oil plant. According to the result in Table 4.4, CRU-1 has the highest percentage of internal cause failure contribution.

Table 4.4: Ranking of FCI internal cause of failure contribution.

No.	FCI of internal failure causes	
	Production unit.	**Percentage of failure contribution.**
1.	CRU-1	58.44%
2.	CFU	34.53%
3.	U-18	26.79%
4.	CDU-1	26.68%
5.	U-19	20.59%

In Figure 4.5(a) and Figure 4.5(b) had shown the comparison of percentage FCI internal cause of failure contribution for each unit in sweet crude plant and lube oil plant respectively.

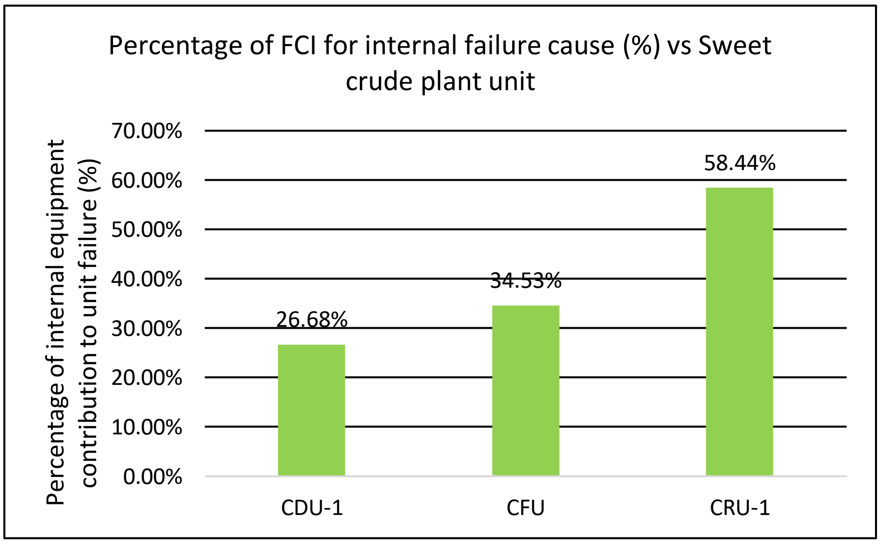

Figure 4.5(a): Comparison of equipment failure contribution in sweet crude plant

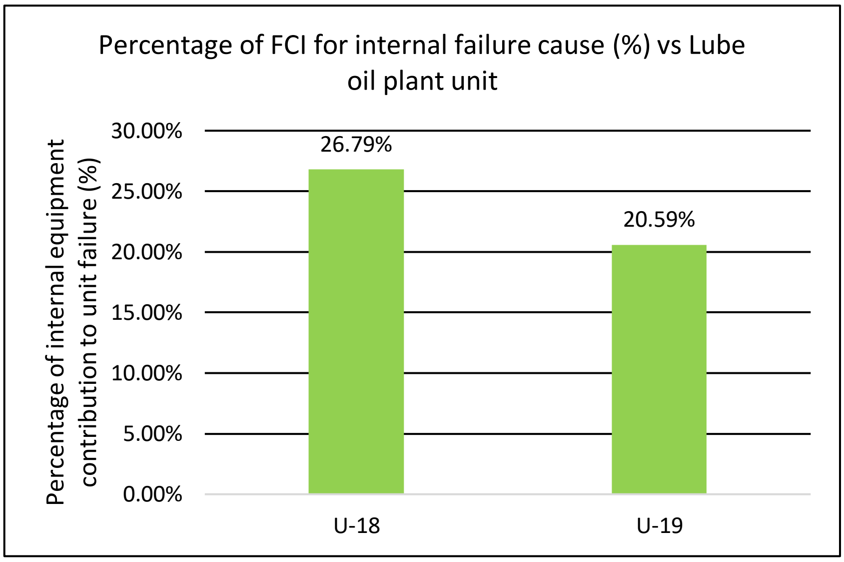

Figure 4.5(b): Comparison of equipment failure contribution in lube oil plant

Since, the highest percentage of FCI for internal failure causes is CRU-1, the researcher had identified that about 94% of internal failure occurred in CRU-1 was due to performance of equipment in CRU-1 which being shown in Figure 4.6. Thus, the equipment performance in CRU-1 need to further investigate in-order to identify the top 10 critical equipment which measured by using FCI and DTCI metrics.

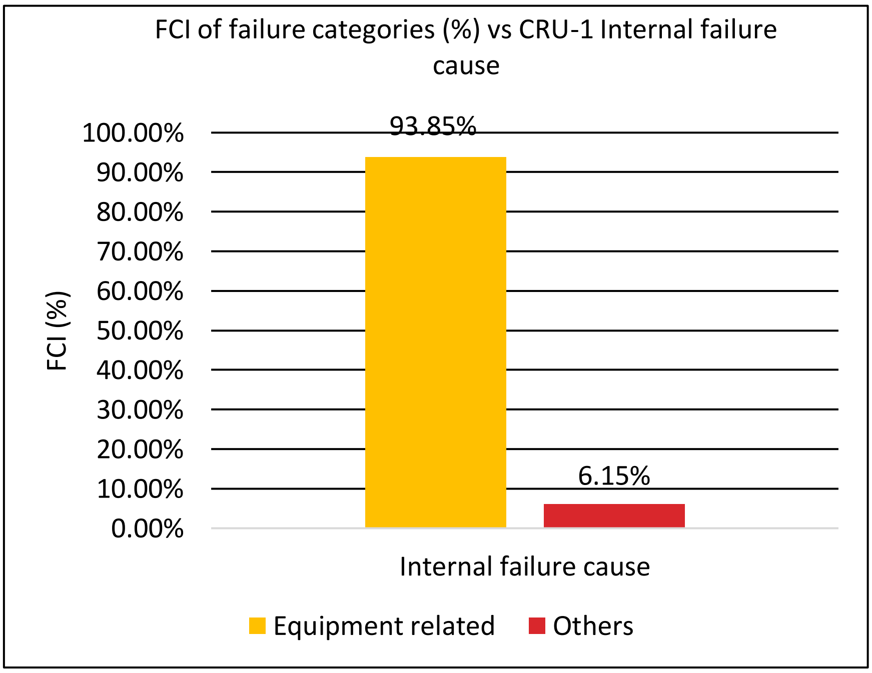

Figure 4.6: Percentage of FCI for Internal Failure Categories.

4.2 RBD Simulation Results – Equipment Level

The equipment level of RBD simulation had referred same data as unit level but the equipment's life distribution is not the same as production unit's life distribution where equipment had applied Exponential distribution, meanwhile production unit applied Weibull distribution. The reason is failure data of equipment has less than five failure for each failed equipment. Thus, it is cannot being computed in Weibull distribution due to less amount of failure.

In Table 4.5 had shown a list of failed equipment in CRU-1. Based on the table, there are total 24 equipment have failed in CRU-1 which effected unit to have unplanned shutdown and slowdown since 2012 until 2018. All of the equipment performance has been constructed in BlockSim in the form of RBD which can refers in appendix 6. Moreover, there are 28 number of failures occurred which means some of the equipment have multiple failures since 2012 until 2018. The difference of life distribution used may lead to the simulation error to more than 1% which referred to the overall internal equipment block.

Table 4.5: List of failed equipment in CRU-1

Combination of equipment in CRU-1		
Failure data from SPDE		
Equipment listing	Quantity	Total no of failure
Pump	2	3
Compressor	6	7
HEX	1	1
AFC	2	1
Furnace	4	4
Refrigeration equipment	1	4
Intrument failure	6	6
Unknown equipment	2	2
Total	**24**	**28**

Basically, there are two results for equipment RBD simulation which are analyzation of critical equipment based on Failure Criticality Index (FCI) and Downtime Criticality Index (DTCI). The RBD configuration for each unit in CRU-1 had been attached in appendix 11.

4.2.1 Equipment Ranking Based on Failure Criticality Index (FCI)

Failure Criticality Index (FCI) is a measured parameter in RBD simulation which indicates the failure rate of the equipment. For example, in Figure 4.7 had displayed that equipment A-1308 has the highest percentage of FCI which is 15.02% of internal equipment failure occurred in CRU-1 is due to equipment A-1308. In other words, there 28 failures occurred since 2012 until 2018 in CRU-1 and 15% of the failure occurred is due to equipment A-1308 which is four number of failures. The ranking of high FCI equipment had followed by compressor K-1301 and Packinox heat exchanger.

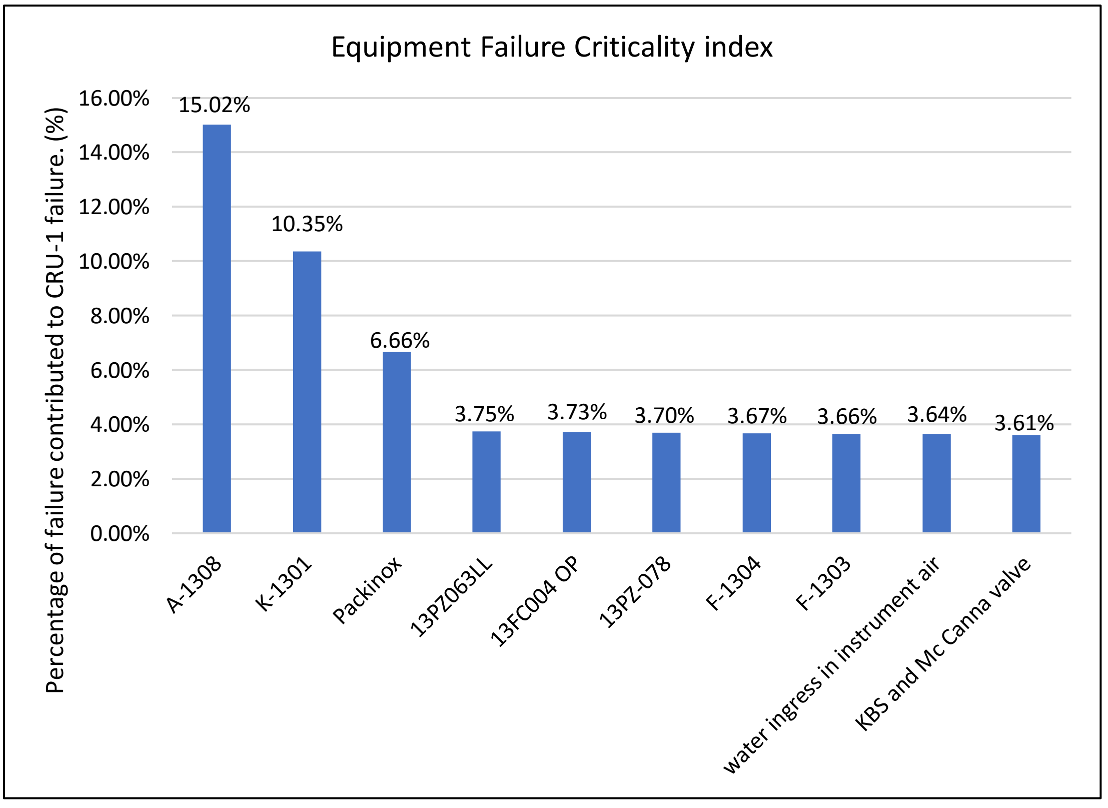

Figure 4.7: Top 10 equipment with high FCI in CRU-1

4.2.2 Equipment Ranking Based on Downtime Criticality Index (DTCI)

Downtime Criticality Index (DTCI) is a measured parameter in RBD simulation which indicates the duration of downtime time need to do corrective maintenance for the failed equipment. In addition, when the equipment were having downtime, the plant could incurred production loss. Thus, the longer the downtime of the equipment, the higher the plant production loss. The RBD simulation had estimated production loss per day for CRU-1 is RM 1.026 million which referred from plant experts.

The top 10 equipment ranking with high DTCI in Figure 4.8 had illustrated that the Compressor Recycled Gas (K-1301) has the highest percentage of DTCI which is 15.09% of the downtime in CRU-1 was due to the compressor with estimated production loss estimated RM 14.68 million.

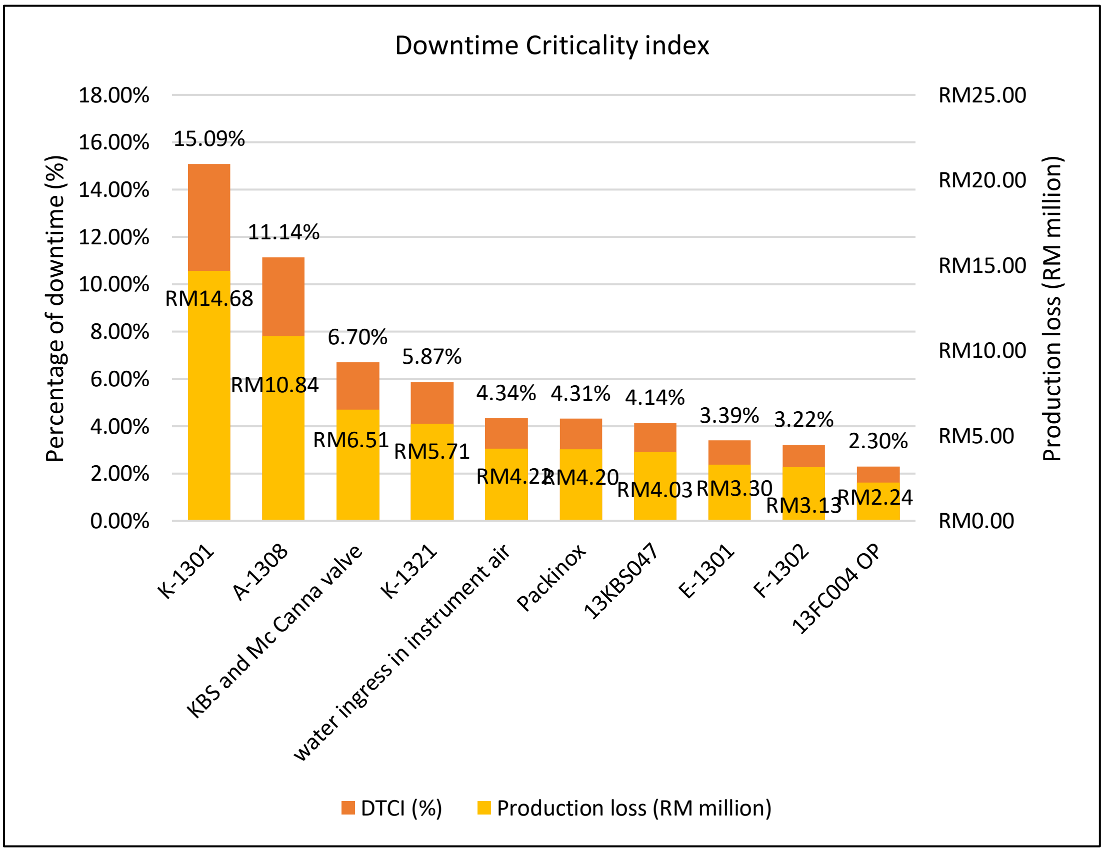

Figure 4.8: Top 10 equipment with high DTCI in CRU-1

4.3 'What-if' Analysis – Component Level

The plant availability can be enhanced by referring to Figure 4.9 which had visualized on how to improve unit availability. The performance of production unit can be improved by improving production unit availability. In-order to improve the unit availability, the production unit need to enhance their reliability and upgrade maintainability. The reliability can be enhanced by prolong the equipment life and maintainability can be upgraded by minimizing the unit downtime for corrective maintenance activity.

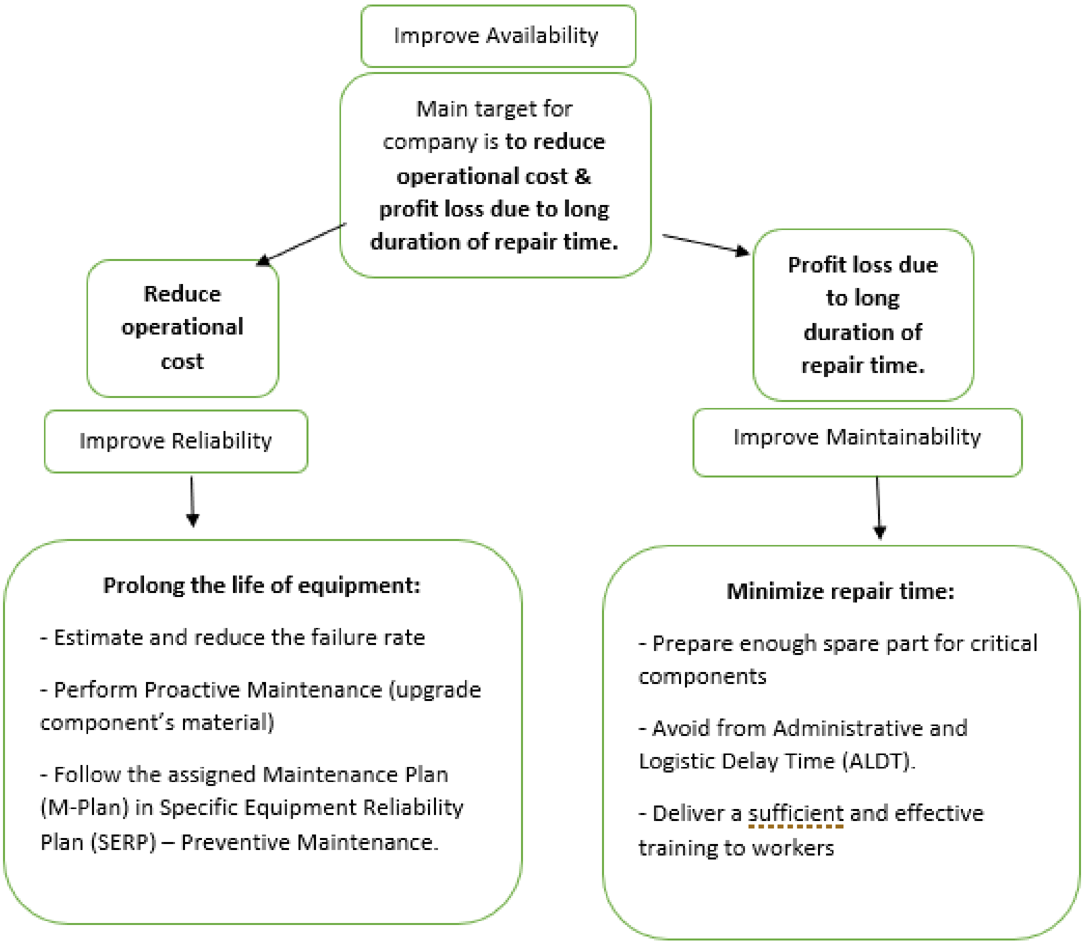

Figure 4.9: Improvement of plant availability, reliability and maintainability.

Basically, what-if analysis is an initiative to improve production unit availability by giving options to maintenance team with the expected unit availability if the action item was being implemented. For CRU-1 case, the critical equipment with high FCI is A-1301 and critical equipment with high DTCI is K-1301. In Table 4.6 had shown the possibilities of action items to be implemented to A-1308 and K-1301. Based on the historical failure data, main issue for A1308 failure are chiller issue and pin hole leak. Meanwhile, for K-1301 are K-1301 trip on LO pump switching and K-1301 tripped. Theoretically, after implementing action items the Mean Time Before Failure (MTBF) of the equipment will be increase and the Mean Time To Repair (MTTR) will be reduced.

Table 4.6: List of action items to improve CRU-1 unit availability

Case no.	Equipment	Issue	Action item	Consequences	New parameters
1	A-1308	Chiller issue	Do RCFA to eliminate the issue.	MTBF increase to 815 days. Where the number of failure reduced to 3 failures. MTTR also reduced to 1.67 days	MTBF = 815 days. MTTR = 1.67 days
2			Improve maintenance activity to reduce the duration of repair time.	Assumed the repair time for chiller issue is reduce by 50% (5 days to 2.5 days) MTTR = 1.88 days	MTBF = 611.25 days MTTR = 1.88 days
3		Pin hole leak	Do RCFA to eliminate the issue.	MTBF increase to 815 days. Where the number of failure reduced to 3 failures. MTTR also reduced to 2.33 days	MTBF = 815 days. MTTR = 2.33 days
4			Improve maintenance activity to reduce the duration of repair time.	Assumed the repair time for pin hole leak is reduce by 50% (3 days to 1.5 days) MTTR = 1.88 days	MTBF = 611.25 days MTTR = 2.125 days
Case no.	Equipment	Issue	Action item	Consequences	New parameters
5	K-1301	K1301 trip on LO pump switching	Do RCFA to eliminate the issue.	MTBF increase to 1222.5 days. Where the number of failure reduced to 2 failures. MTTR also rise to 6.5 days	MTBF = 1222.5 days. MTTR = 6.5 days
6		K-1301 tripped on 9/2/2013-20/2/2013	Do RCFA to eliminate the issue.	MTBF increase to 1222.5 days. Where the number of failure reduced to 2 failures. MTTR also reduced to 1.5 days	MTBF = 1222.5 days. MTTR = 1.5 days
7			Improve maintenance activity to reduce the duration of repair time.	Assumed the repair time for K-1301 tripped is reduce by 50% (11 days to 5.5 days) MTTR = 2.83 days	MTBF = 815 days MTTR = 2.83 days

The result of the 'what-if' analysis had been illustrated in Figure 4.10. Assumed that the targeted CRU-1 unit availability is 94.5%. By having this analysis, the maintenance and management team can estimate the best action item to be implemented in-order to achieve the targeted KPI. Furthermore, the maintenance team also can verify which action items are possible to be implemented and directly can estimate the CRU-1 unit availability.

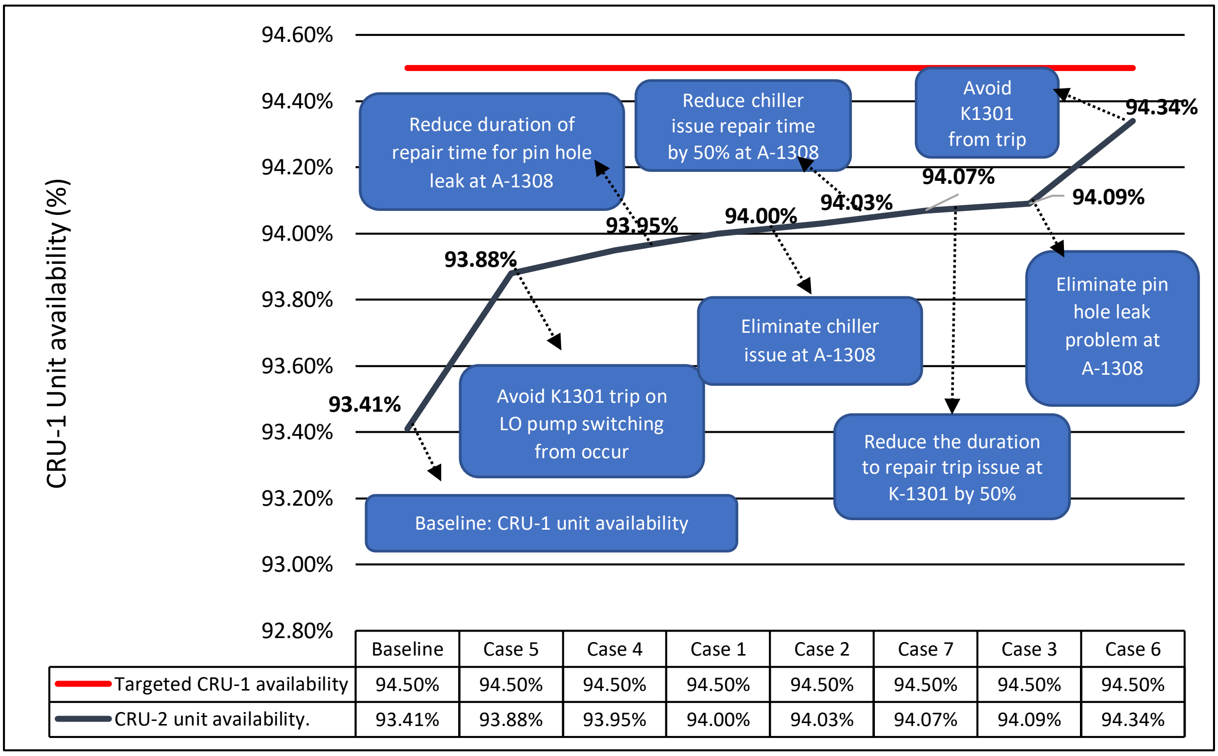

Figure 4.10: Improvement of CRU-1 unit availability by each case action items

4.4 Discrete Event Simulation (DES) Result.

The refinery plant utilization cannot be modelled using DES method because the simulation model required the researcher to identify product flow rate in and out of each equipment in refinery plant. As been mentioned before, the purpose of this model is to focus more on the throughput in refinery plant in-order to find the bottleneck of refinery production processes.

The problem is the researcher cannot get the document of equipment flowrate from refinery plant because it was classified as confidential documents. The researcher could continue the simulation modelling by assuming the in and out of equipment flowrate, however the result of the simulation will be useless and not tally with the RAM model RBD simulation result.

4.5 Discussion

At this point, most of the project objectives have been achieved. The performance of sweet crude refinery plant and lube oil plant have been modelled in RBD simulation model to find percentage of production unit availability. The simulation was being carried out by using BlockSim software and the parameters of the model had been analysed by using Weibull++ software. As the result for sweet crude plant production units, CDU-1 has the lowest unit availability, 92.34% then was followed by CRU-1, 93.41% and CFU, 94.44%. Next, production unit in lube oil plant, U-19 had lower production unit availability with 91% compared to U-18 92.26%.

Furthermore, for equipment level analysis the researcher had selected CRU-1 because this production unit has the highest failure contribution of internal failure cause. Thus, the researcher had listed out top 10 critical equipment which measured by using FCI and DTCI metrics where the most critical equipment for FCI metric was Refrigeration Equipment (A-1308) and the most critical equipment for DTCI metric was Recycled Gas Compressor (K-1301). Lastly, the researcher had further analysed the most critical equipment in component level analysis. In this level the researcher had implemented 'what-if' analysis to give options to operation and maintenance team in-order to enhance percentage of CRU-1 unit availability. Finally, the company has a potential to achieve the targeted unit availability of CRU-1 which is 94.5% by implementing each proposed action items which was being listed in previous section.

Unfortunately, the searcher could not conduct DES method modelling. The reason is that the data required for the simulation model cannot be shared to other party as it was classified as confidential data.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1. Conclusion

As the conclusion, the management team of a company can use RAM study analysis as a tool to control plant utilization of refinery plant which must be tally with the company's business objectives. The reasons are the RAM study can estimate the production unit availability, estimate the next time of production unit failure and estimate the production lost. Therefore, by having that advantages the operation and maintenance team can focus on critical equipment by preparing enough spare parts and frequently do pro-active maintenance on it. From RBD simulation result, crude reformate unit (CRU-1) contributed the highest internal cause of failure. Therefore, further study for equipment performance had been conducted and had identified the critical equipment quantitatively. Refrigeration Equipment (A-1308) and Recycled Gas Compressor (K-1301) have been declared as critical equipment due to high failure rate and significant downtime to do corrective maintenance. The improvement to the equipment's availability had been conducted by prolong the MTBF and reducing MTTR of the critical equipment. As the result, the unit availability was being improved.

To enhance the credibility of the results presented in this paper, it is necessary to work on real case study. Thus, every step in this study need verification from plant experts because to ensure that the analysis is on track with real operation. Other than that, operation historical failure data collection also crucial to determine the credibility of the presented results. This case study had demonstrated some abilities of RAM model which can be utilized by Reliability Analyst to apply RAM principles in industry.

5.2. Recommendations For Future

1. The knowledges of this project can be applied to any industry in-order to assess their plant performance especially plant availability.
2. The result of this study will be closed as in real operation if the data gathered is accurate and well described.
3. Proper training regarding the usage of ReliaSoftware should be conducted to reduce error while conducting analysis.
4. The performance of production units in sweet crude plant and lube oil plaint need to keep on track from time to time.

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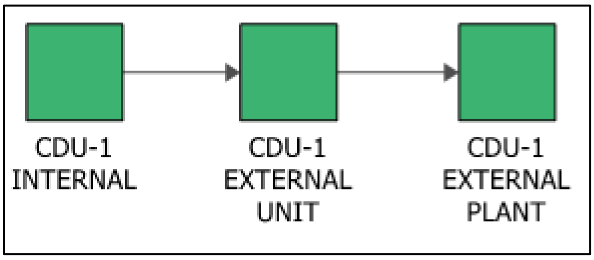
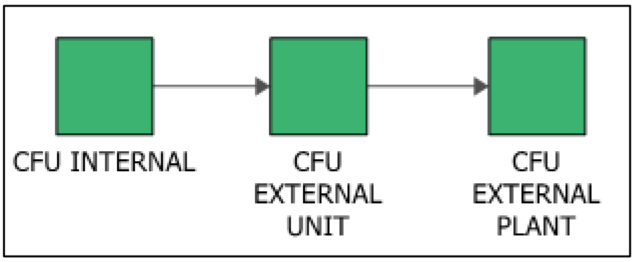
APPENDICES

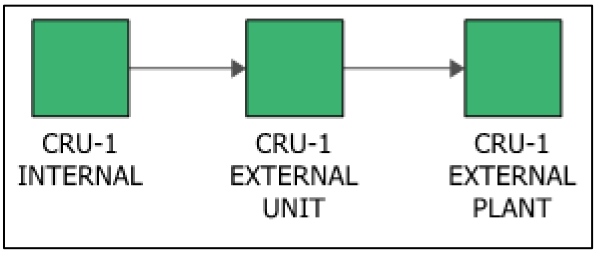
APPENDIX 1: RBD CDU-1



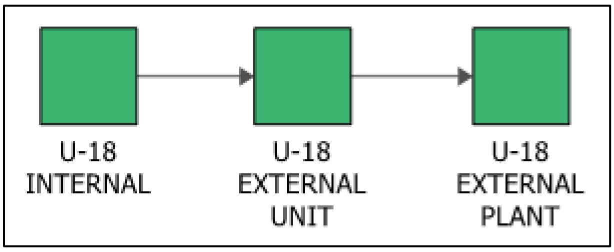
APPENDIX 2: RBD CFU



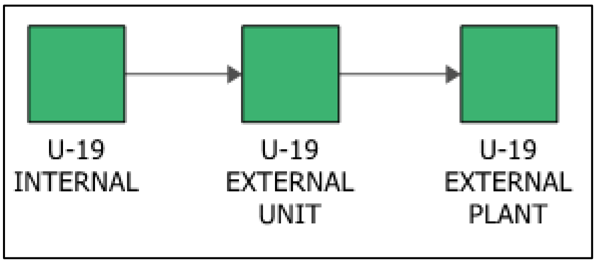
APPENDIX 3: RBD CRU-1



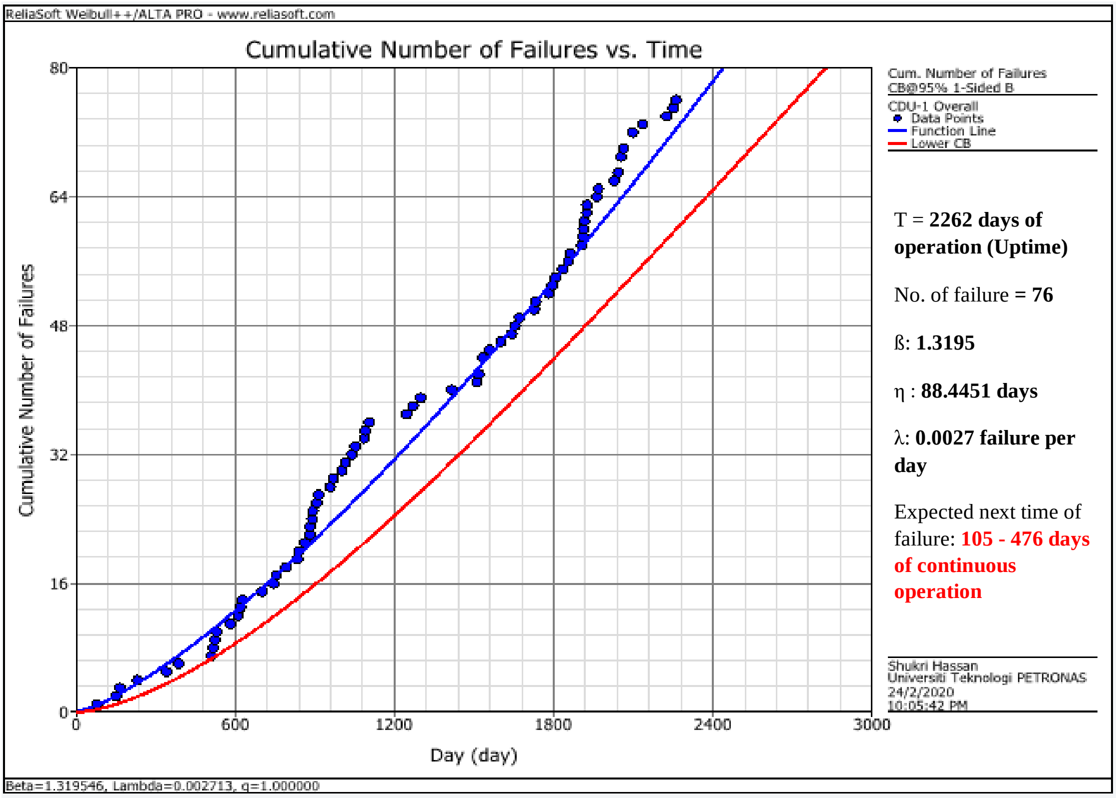
APPENDIX 4: RBD U-18



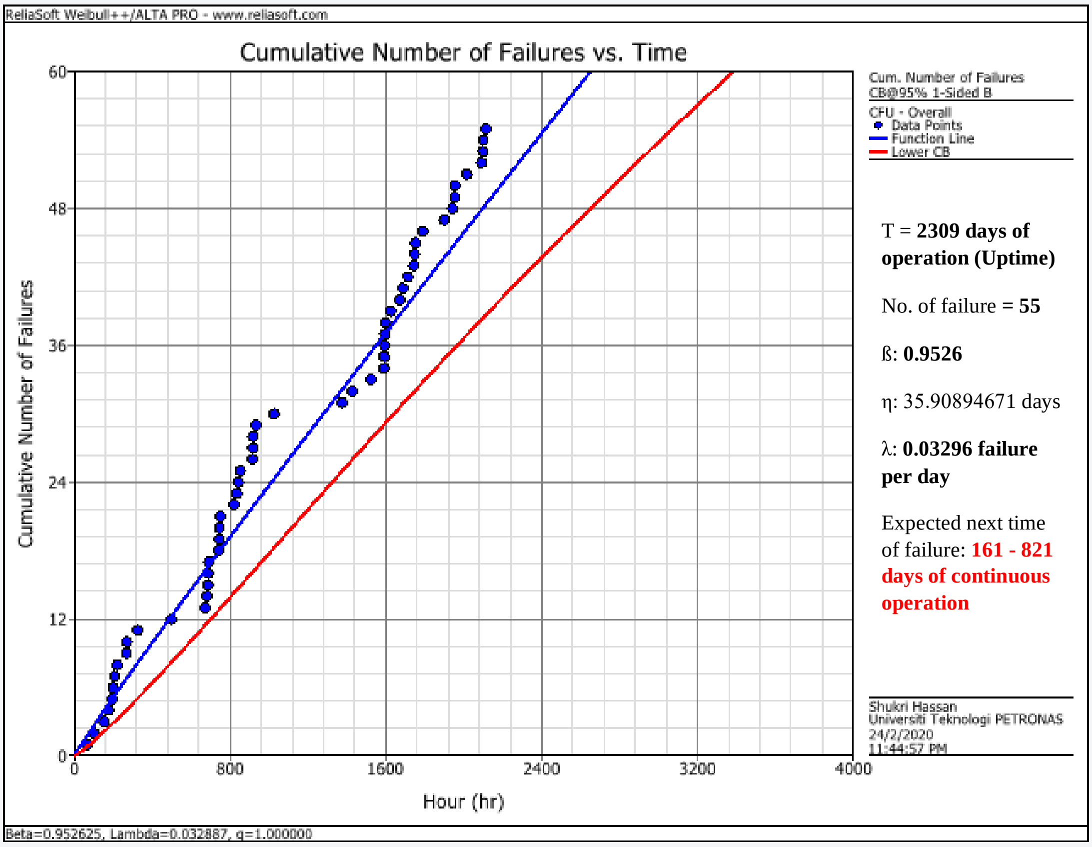
APPENDIX 5: RBD U-19



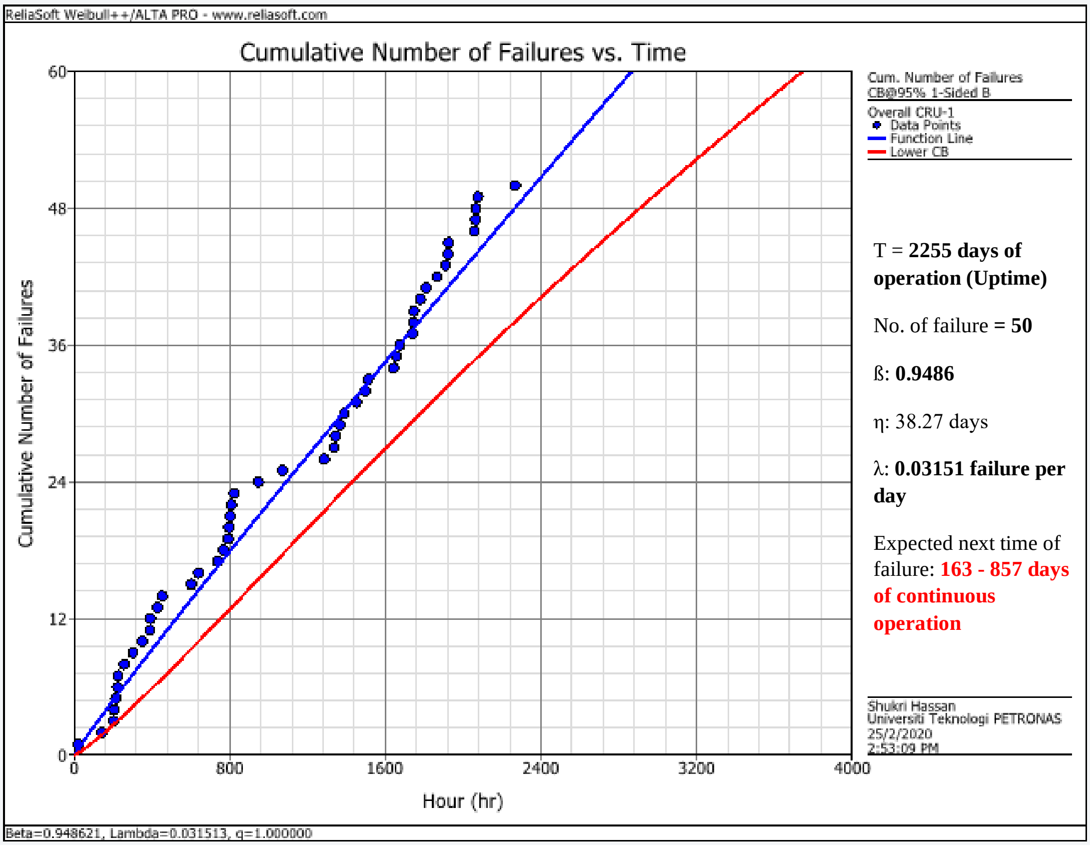
APPENDIX 6: Linearized probability of failure graphs for CDU-1



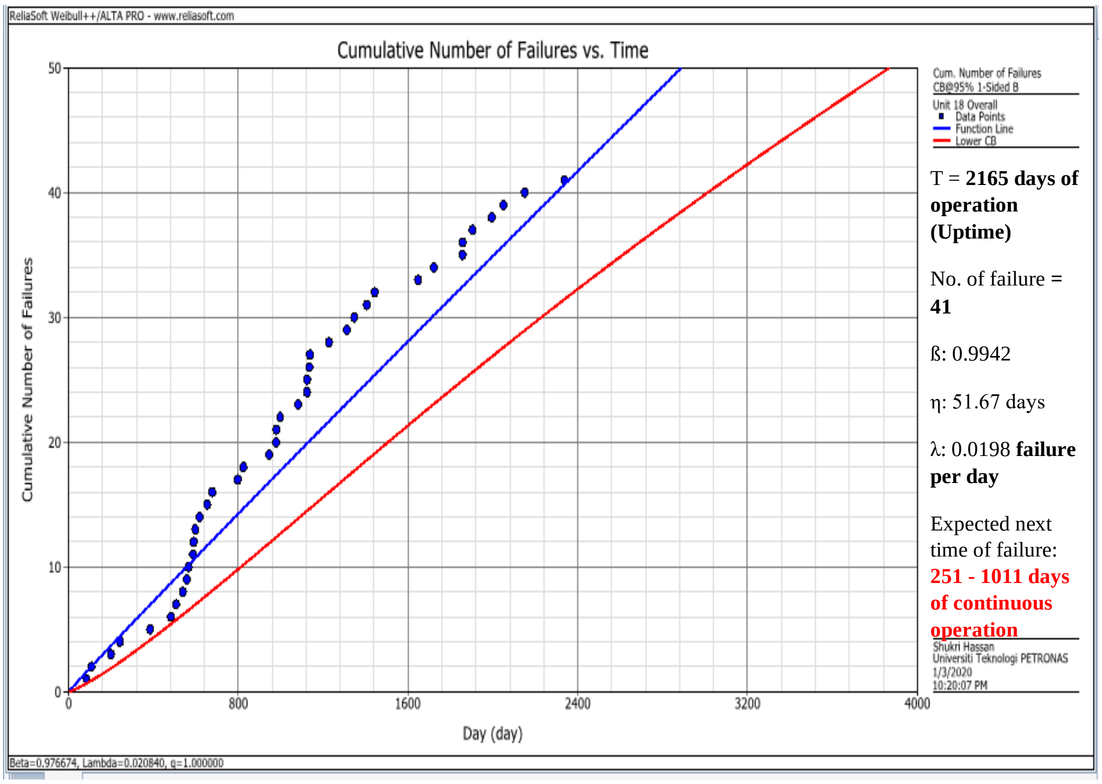
APPENDIX 7: Linearized probability of failure graphs for CFU



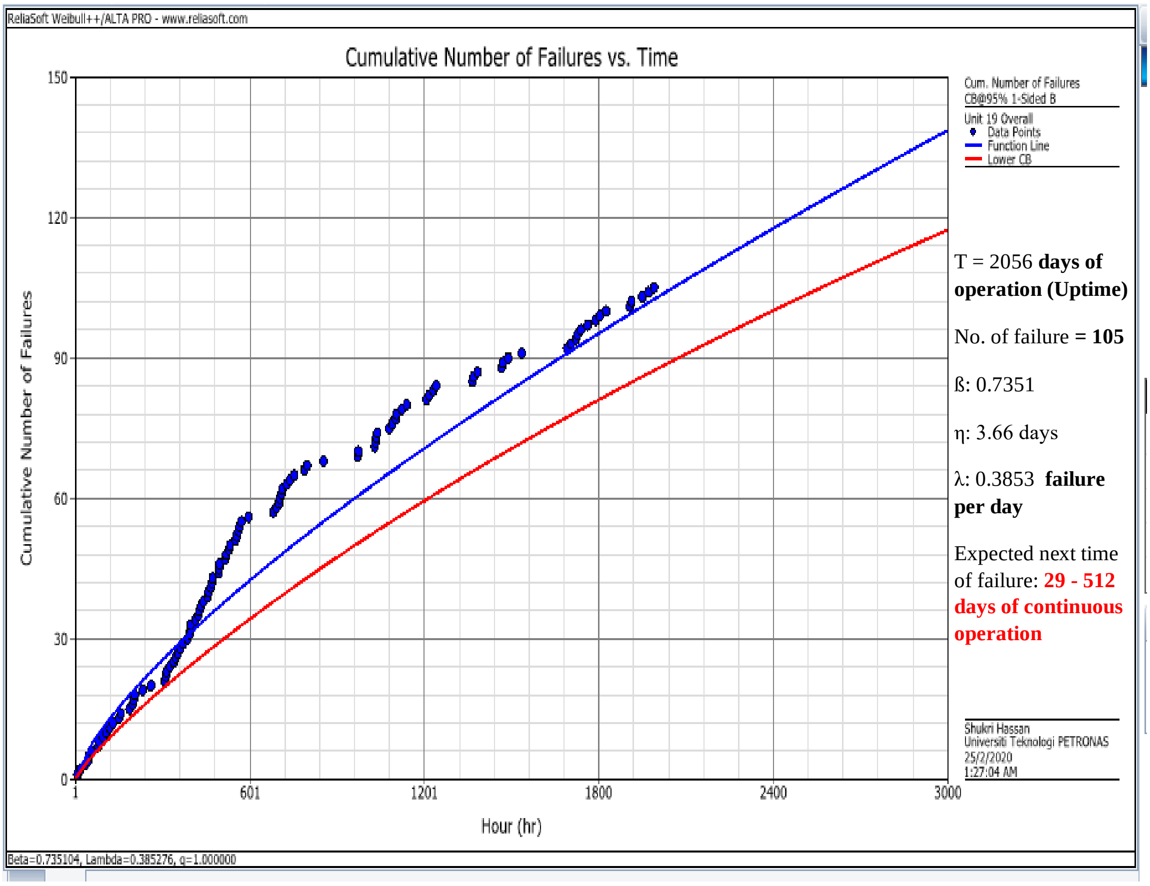
APPENDIX 8: Linearized probability of failure graphs for CRU-1



APPENDIX 9: Linearized probability of failure graphs for U-18



APPENDIX 10: Linearized probability of failure graphs for U-19



APPENDIX 11: Configuration of CRU-1 equipment RBD in BlockSim