SPARE PARTS OPTIMIZATION (VALVE) FOR BOILER AT COAL FIRED POWER PLANT

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This report is submitted
In fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Spare Parts Optimization (Valve) For Boiler At Coal Fired Power Plant" is the result of my own work except as cited in the references

Signature	:	....
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Date	:	23/5/2017

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Plant and Maintenance with Honor).

Signature :. ....

Name of Supervisor : Dr. Reduan Mat Dan

Date : 23/5/2017

DEDICATION

To my beloved parents En. Ahmad Yaakob, Pn Ummi Kelsom Fei@Ghazali, all TNBJ's staff, supervisor Dr. Reduan Mat Dan and friends who are always encourage and support me while completing this project.

ABSTRACT

Spare part is one of the common precaution used by a company to ensure the availability of their machine in an optimum level. By optimizing the spares inventory, the power plant company can reach the optimum level of availability and indirectly will increase the reliability of the plant. Any lack of spares can lead to company losses in form of maintenance cost, operation loss and material loss. In addition, the lack of spare also can increase the mean time to repair and lead to the production stoppages. However, if the number of spares are more than the requirement, company will bear some losses as the spares will not be in used and may lead to the obsolete items. Besides that, if the spare was protected by an insurance and being kept in the inventory, it may lead to the waste of money and inventory space that can be used in another purpose such as preventive and predictive maintenance. Thus, the company needs to analyse the failure and the stock movement to optimize the spare and increase the reliability of the plant. There are some analysis that can be used to optimize the number of the spare such as Pareto analysis, Failure Trend analysis and Movement analysis. To conduct this analysis, engineer and technician must be aware and monitor the movement of the spare to get a significant data that can be used in the analysis. Therefore, the analysis can be more accurate and the optimised list of spare can be issued by the company. All the steps to optimizing spares was covered in this paper.

Keywords: power plant; spare parts; inventory; Pareto analysis; Failure trend analysis; Movement analysis, cost; optimize.

ABSTRAK

Alat ganti adalah salah satu langkah berjaga-jaga yang biasa digunakan oleh syarikat untuk memastikan adanya mesin mereka di tahap yang optimum. Dengan mengoptimumkan inventori alat ganti, syarikat loji kuasa boleh mencapai tahap optimum ketersediaan dan secara tidak langsung akan meningkatkan kebolehpercayaan kilang. Sebarang kekurangan alat ganti boleh menyebabkan kerugian syarikat dalam bentuk kos penyelenggaraan, kerugian operasi dan kerugian bahan. Di samping itu, ketiadaan alat juga boleh meningkatkan purata masa untuk membaiki dan membawa kepada kadar pengeluaran terhenti jika kegagalan tersebut berpunca daripada mesin kritikal. Walau bagaimanapun, jika jumlah alat ganti lebih daripada arahan kerja, syarikat akan menanggung beberapa kerugian sebagai contoh alat ganti tidak akan di digunakan dan boleh menyebabkan alat ganti tersebut usang. Selain itu, jika alat ganti ini dilindungi oleh insurans dan disimpan dalam inventori, ia boleh membawa kepada pembaziran wang dan ruang inventori yang boleh digunakan untuk kegunanan yang lain seperti penyelenggaraan pencegahan dan ramalan. Oleh itu, syarikat perlu menganalisis kegagalan dan pergerakan untuk mengoptimumkan bilangan alat ganti dan meningkatkan kebolehpercayaan kilang. Terdapat beberapa analisis yang boleh digunakan untuk mengoptimumkan bilangan bahagian seperti analisis Pareto, analisis Gaya Kegagalan dan analisis Gerakan. Untuk menjalankan analisis ini, jurutera dan juruteknik perlu menjaga dan memantau pergerakan alat ganti untuk mendapatkan data penting yang boleh digunakan dalam analisis. Oleh itu, analisis akan menjadi lebih tepat dan senarai alat ganti yang telah dioptimumkan boleh dikeluarkan oleh syarikat. Semua langkah-langkah untuk mengoptimumkan alat ganti telah dibincangkan dalam kertas ini.

Kata kunci: loji kuasa; alat ganti; inventori; analisis Pareto; analisis Gaya kegagalan; analisis Pergerakan, kos; mengoptimumkan.

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I would like to express my deepest appreciation to my supervisor Dr. Reduan Mat Dan for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

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LIST OF ABBREVIATIONS

MTTR	Mean Time To Repair
MTBF	Mean Time Between Failure
MTTF	Mean Time To Failure
GF1	Generate Facilities 1
OEM	Original Equipment Manufacturer
RAM	Reliability, Maintainability, and Availability
CBM	Condition Based Monitoring

CHAPTER 1

INTRODUCTION

1.1 Background

It is now well recognized that an efficient maintenance system will decrease the cost for maintenance in a company or organization. To decrease the downtime of a maintenance, the company must define all the uncontrolled and controlled variables in the power plant. Besides that, there are some methods that researcher can do to reduce the maintenance cost in the power plant. Firstly, minimize bottlenecks within the integrated plant. When the congestion to do the maintenance activity in the plant decrease, the mean time to repair (MTTR) will decrease. Consequently, the cost for maintenance activity will decrease.

A systematic system can also decrease the cost for maintenance. As example, generate shift on some works or process it will makes the flow of production move smoothly and decrease the time for performing the activity especially maintenance activity. Besides that, by regulating the predictive maintenance and the relation with the management can increase the overall equipment availability. This is because, by performing a predictive maintenance correctly, researcher can estimate the time for machine to fail and the parts that need to repair or replace. This indirectly will save the cost for spare parts and decrease the MTTR in the plant.

Alteration of the plant operations especially on critical facilities in the plant such as pump, valve and compressor will increase the performance on the current production systems. This can be related with the availability of the machine. When a machine is available for the production, the loss of the plant can be decreased. By optimizing the spares, indirectly will increase the reliability and availability of the machine to the plant. Furthermore, if the spares required to repair a failed machine are ready, the time for the machine to operate normally will decrease.

By optimizing the spare, the company also can eliminate unnecessary spares that do not produce any benefit to the plant. The cost for store and insurance also can be reduced. In addition, a systematic spares management also can be produced as the spares are optimized. The maximum number of spares also can be determined by analyzing the usage of the spares in the past year. By observing the trend of the spares usage, a set of quantitative data can be obtain. This data can be used as a medium to calculated the effectiveness of the spare parts between present management and the propose solution.

Additionally, by dividing the spares into several types and perform some analysis such as Pareto Analysis and Movement Analysis, the reliability of a plant can be improved. Furthermore, company can estimate how fast the spares have been used. Consequently, company can decrease the loss and the estimated number of spare can be optimized. As a simple conclusion, optimize the spares inventory will affect the company expenditure by decreasing the lost in maintainability and productivity in the plant.

1.2 Problem Statement

The power plant company indicates some loses when there was a failure occur on the machines at the plant. The production of the plant will be stopped if any of critical machinery failed and this will affect the company profit. The company found some factors that may affect the failure such as high pressure and temperature during the operation, lack of preventive and predictive maintenance in the plant and lack of maintenance awareness at the plant. The plant perform the predictive maintenance as a method to decrease the failure. However, the excessive time required to repair the machine come to be a major problem that cause the production to stop longer than what have been expected by the company. There are many factors that influent the problem. By observing the problem, the maintenance department found that the main cause of the excessive time for repair was lack of spares. This is because most of the parts on the critical machine is very expensive and some of the parts must be imported from oversea. The lack of spares at critical time will make the company to spend a lot of money on it. Besides that, some of the spares in the inventory is not moving at all by years and it reduce the space in the inventory. This is very costly as the old spares have their own expired date that require it to be disposed and most of the critical expensive spares need insurance that must be paid by the company monthly. By concluding the problems, the maintenance department agreed that the spare parts management need to be more effective by lowering the loss that cause by the spare. By optimizing the spare management, the loss of the company can be reduced and the times for repair the machine are also can be decrease.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To reduce the loss of company by optimizing the spare parts management in the plant.
2. To increase the reliability and availability of the machine in the plant

1.4 Scope of Project

The scopes of this project are:

1. The results are only from GF1 facilities at power plant are presented in this report. The previous results of the maintenance cost are obtained from another set of measurement conducted by the contractors, technicians and engineers in the power plant.
2. The data obtained for education purpose only due to confidential data and limited access to the whole power plant.

1.5 EXPECTED RESULT

The expected result of this project are:

1. Maintenance cost can be decreased due to spares optimization.
2. A systematic maintenance system can be performed.
3. Time taken for maintenance activity can be decreased.
4. The company profit increased.

1.6 GENERAL METHODOLOGY

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review

   Journals, articles, or any materials regarding the project will be reviewed.

2. Field work

   Inspection

   - The plant layout in the power plant will be inspected and the occupants will be interviewed to identify the cost of maintenance at the power plant.

   Measurement

   - The measurement will be conducted at the area Generate Facilities 1 (GF1) at the power plant. Another measurement will be taken directly from engineer at the power plant. Measurement data from contractors work on the maintenance activity before will also be collected for comparison.

   Calculation

   - Calculation of the maintenance cost such as MTTR will be made based on the data input from the measurement.

   Analysis and proposed solution

   - Analysis will be presented on how we can reduce the maintenance cost and also the root cause of the problem. Solutions will be proposed based on the analysis.

3. Report writing

   - A report will be written at the end of the project on this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Optimizing Spare Part

There are two main part to optimize the level of spare parts which are cost and the effectiveness of spare parts. By holding absolute minimum number of spare which is necessary to meet the needs, indirectly will decrease the cost of spare part. However, minimizing the number of spare parts is not the only things that must be considered. This is because, the availability of the spare parts when it is required is also an importance measures of decreasing the time of maintenance activity or in other words it called as effectiveness of spare parts.

Furthermore, planner should be aware of the spares strategy that can be used to optimize the number of spare parts in a plant. By knowing the number of spare needed for the preventive maintenance activity which is already a routine for the maintainer, they should know the pattern and can predict the requirement for spares. This will increase the effectiveness of the spare parts. For corrective maintenance, there must be a pattern of it for the past year and this pattern can be a benchmark to estimate the number of spares.

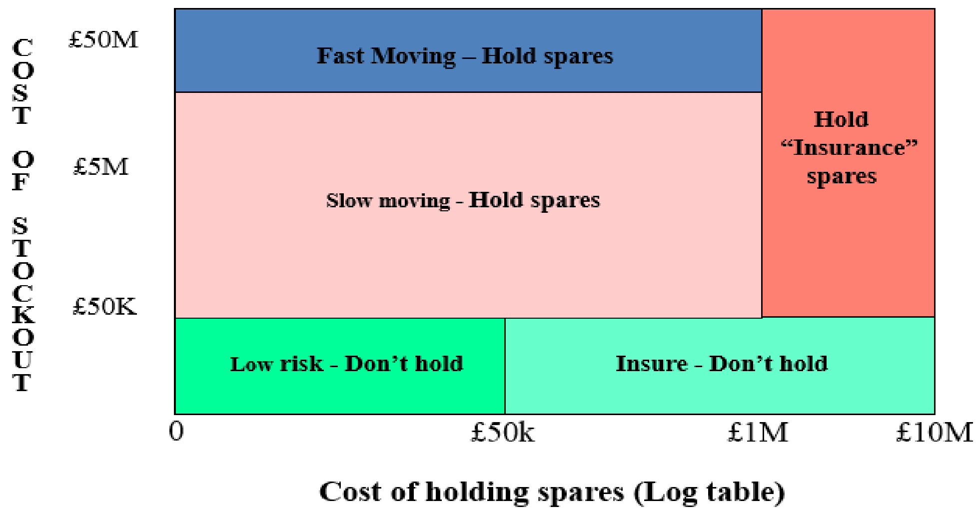

Figure 2.1.1: Example of spare management strategy (Paul Wheelhouse, 2012)

In addition, planner must be aware to the spare policy by considering all types of spare and how fast the spare is moving. There are several types of spare that must be categorized to ensure their need. Increase efficiency of the plant requirement will minimize the machine downtime and availability in the plant. A good spare policy also will minimizing the MTTR by installing the suitable part in a short time. Furthermore, a good spare management can also decrease the cost for part holding which is one of critical problem on spare management.

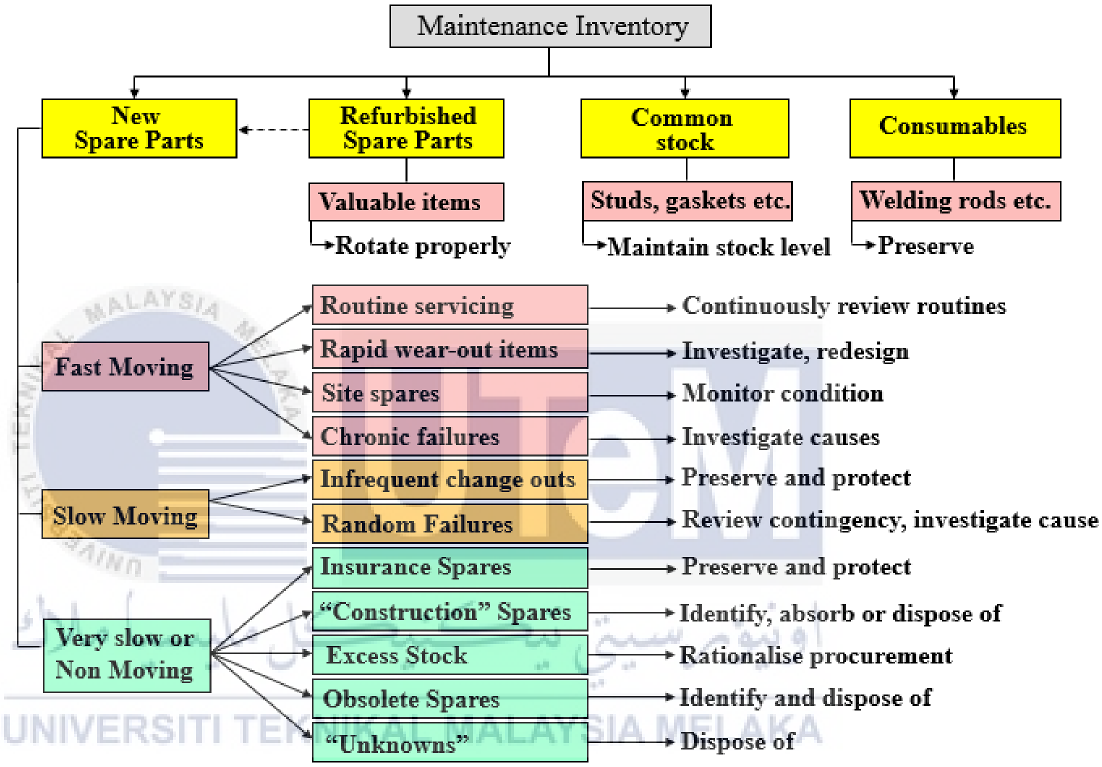

Figure 2.1.2: Type and policy of spares (Paul wheelhouse, 2012)

Spares management requires many topic to be covered such as the need of the spares, lead-time, factors that will affect spare holding and the strategies to reduce the inventory. The need of the spares is importance because 1/3 to 1/2 of the maintenance expenditure is only on spare parts inventory. Additionally, maintenance without necessary parts will increase the loss of a company (Paul Wheelhouse, 2012). All this topic must be covered to ensure that the plant meet all the requirement for optimizing their spare parts.

2.2 Spare Parts Inventory for New Spares

New spare part is a substitutable part that kept in the inventory and will be used for replacement to the failed unit, UK White Goods (2016). By decreasing the Mean Time to Repair (MTTR), indirectly will decrease the cost for maintenance activity. There are three types of new spare part which are fast moving, slow moving and very slow or non-moving spare parts.

Fast moving spare part is spare that need a less time to be stored in the inventory. This spares are usually selected by analysis on the routine serving done by the company. Analysing the rapid wear-out items and the common failure on a machine will indicate the time and the estimation number for failure. This indirectly will come out with a set of spare required in certain time. Therefore, the spare selected will be moving fast and take a short time to be replaced.

Slow moving spare can be consumed as spare that need a longer time in the inventory as the necessity for replacement is lower than fast moving spare. This types of spare usually for preserve and protect the production rate as the part is rarely to be fail. Furthermore, this spare also be ready for a random failure that may be happen on the machine. This will lower the time for the machine to operate again or in the other words, the availability of the machine to the production rate can be increased.

The final one is very slow or non-moving type of spare part. This usually the most valuable spares in the inventory. This is because most of the part was covered by the insurance as the company needs to make sure that the part is still usable and protected for a long time. Many people are targeting the slow moving inventory as a silver bullet for the spare part optimization. Usually, this is based on the belief that being a slow moving spares prove they are not really needed. This is mistaken because the spares could be needed sometimes but infrequently, Phillip Slater (2016). Additionally, the slow moving spares may for the critical machinery that needs to use on time or else the production will stop. Therefore, before the failure occur, the best things to do is make a spare so that the availability of the machine can be increase.

2.3 Spare Parts Inventory for Repairable Items

Spare parts inventory of a power plant typically accounts for more than 5% of the operating cost. An excess of spare parts will leads to a high holding cost and it slow down the cash flows, whereas insufficient spare parts result in costly production delays and causing a negative impact on the plant performance. Different companies will need a different type and number of spare parts. Spare parts inventories are different from other types of inventories in companies, Cohen et al (1990). Rego et al (2006) have pointed out several important factors on the spare management for the inventories:

- Customers have increasing expectations and the concerning of quality associated with the services and products. The rate of failure is already a concern and the delay in repairing due to lack of spare parts will degrade the clients' negative perception;
- Some of the items have a high demand such as parts with great wearing and related to the preventive maintenance, but the great majority has irregularly demand.
- The increasing complexity of products and the life cycles saving will generate an increase on an amount of active codes and risk of undesirability.

Repairable items are components or assets that after a failure occur,they will be submitted to a repair cycle to be used again as a substitute of been discarded, Fritzsche et al (2016). It suggests that a repairable item spare parts inventory system must have a repair shop where failed components are repaired, as well as a warehouse where spare parts are stocked (Perlman and Levner, 2010).

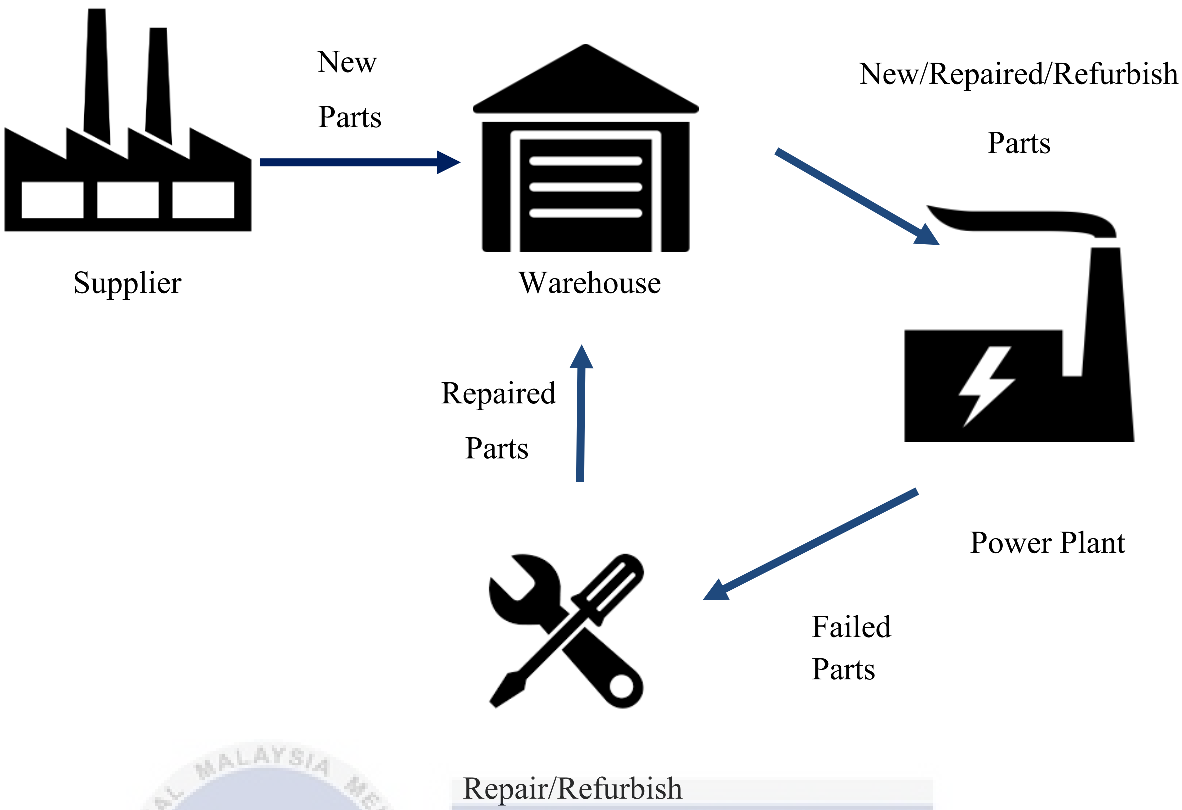

Figure 2.3: spare parts inventory for repairable items

Based on the **Figure 2.3** above, it is considered that spare parts are usually bought from the same supplier and delivered to the warehouse. When a component installed on the plant's equipment fails, it is removed and sent for repair or refurbish shop to be repaired. The fault component will be replaced by the new one from the warehouse. If there is no spare part for critical machine in the warehouse, thus production of the power plant will stop until a new part is provided.

When the repairable component fault, it will arrive in the repair shop for the repair process. There are also parts in the plant which can be refurbished such as journal bearing. This process also can decrease the cost for buying a new part. When the repair process ends, it will be sent back to the warehouse and standby for replacement if the failure occur. The repair process can be considered to be perfect if the repaired components returns as good as a new condition. But if imperfect process have been applied, the repaired components will keep a residual degradation. Imperfect repair models were presented by Do Van at al (2012) and Doyen et al (2004). In this paper, consider that the repair place has an infinite capacity because usually this company will pass it to the contractors and no degradation occurs.

2.4 Spare Parts Inventory for Common and Consumable Items

Paul wheelhouse stated that there are four types of spare parts which are new, refurbish, common and consumable. The common and consumable spare are classified in different type. Researcher disagree with that statement because they should in the same class which is consumable. Consumable is part or material used by an individual or a company that must be replaced recurrently because they will wear out or finished, Y.Ming et al (2013). They also can be defined as the spares of end product that have been used up or permanently reformed in the process of manufacturing and repairing, G.Ojeih (2016) .

As what have been mentioned by Paul, the example of common spares are screws and the consumable spares are welding electrodes. Researcher state that all of the example are defined as consumable as the company used it until wear out or finish. Both of this types also must be replaced regularly as it have been commonly used in the plant. There are two type of consumable spares. First is durable spares which can be store in a time while the other type is nondurable spares which only can be store in a short time. Furthermore, the example of non-durable spare is ricin that used for water treatment which have their expired but if it been used, so it consider as must be replace.

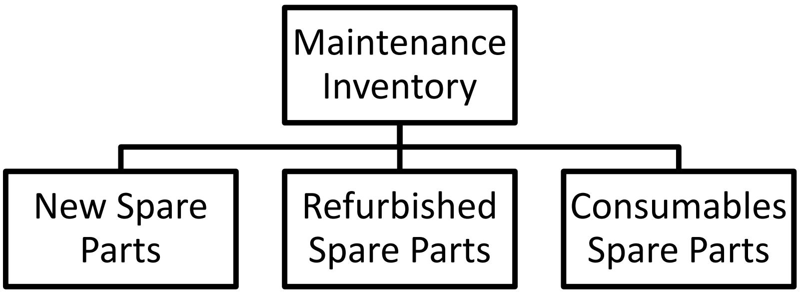

Figure 2.4: Spare parts classification

Researcher believed that the two types of spare must be classified together as they will be used commonly and will be replaced regularly. Therefore **Figure 2.4** is the new spare parts classification.

2.5 Inventory Management

A good spares management will increase the company reliability by decreasing the repair time. To manage a good inventory storage, first look deeply on the need. By doing some research and monitor the repair part time by time, will altered up the result and get more accurate data. Observe the holding inventory, is the stored spares have benefit to the availability or only a waste. Eliminating the unnecessary part will increase the effectiveness and reliability of a plant, Mladen et al (2010)

Lead time is an important things that must be reviewed. This is because all of the spares have a sequence to be followed before it can be stored. Furthermore, if the spare is imported from the other country, the lead time will increase and lead to further delay from receiving the spare. There are several element of lead time that must be facing by company before they proceed to storing part as illustrated in **Figure 2.5**. By minimize the lead time with a proper management the availability and reliability of the spare can be increase.

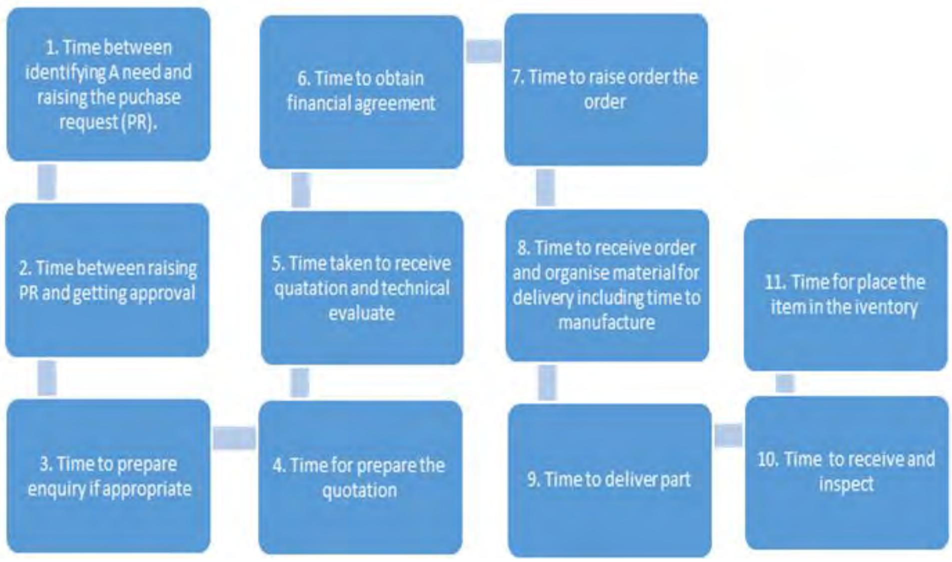

Figure 2.5: Lead time elements

Besides that, holding spares for long time is not economical. This is because the money is tied up in stock and it cannot be used for anything else. Additionally, it is very costly to store the part inform of insurance, storage and labor. As the spares are not in use at a long time, the potential for the spares to be damaged is high and that is why the insurance was needed to cover the items. There is also a lost in opportunity toward the usage of the money to another use and it will affect the company profit indirectly. As example, assuming the lost opportunity for the holding the spares is 10% per year and add with the cost for warehouse that need to be built, maintained and labor which is 5% per year, then total up it will become 15% per year and surely that is a lot of money that have been wasted , Paul Wheelhouse (2012).

2.6 Strategies to Reduce Inventory cost

By reducing the number of inventories will consequently decrease the cost for storage, labor and damage spares. Consequently the company profit will be increased by reducing expenses, Jose et al (2010). There are some strategies that can be followed to reduce the inventory. First, standardization or interchangeability the spares. As well known, a plant normally consist of variable size and type of machines and equipment. By standardization of the machines and equipment, company can reduce the number of options. As example, there are three variable type of motors in a plant that consist of same spec, and by reducing the type which have a same spec but difference in size and SI unit, indirectly will decrease the spares inform of three difference types to be only one type and it is interchangeability to each other, K.Cobbert et al (2000).

Besides that, the rationalization of supplier and spare location is one of the strategy to reduce the inventory. Rationalization is reduction or addition of something toward a complete optimize set of result which increase the effectiveness to the system, steve pak (2016). Through rationalization of the spare part, a rational number of suppliers that needed to be align with can be optimize. Thus the company can eliminate the potential risk that may be facing on the untrusted suppliers.in other hand, by adding the number of suppliers, the plant can save the storage and more variable price of space can be choose, CIPS (2013). In addition, by rationalization the spare location, company can rearrange the spare and if there is enough space for store the spares so that no need to build another warehouse and consequently will decrease the construction cost. In addition, by rearrange the spares and calculate the rational number of spare needed, company can eliminate the unnecessary spares and estimate the optimize number for the spares.

Another method that can be used is by finding alternative spare. There are many others market that manufacture the same spare parts other than the Original Equipment Manufacturer (OEM). Thus take a step to buy it from others by considering the effect and the quality of the spares. There is no doubt that many of non-OEM manufacture have a good quality product and even better, but to find a trusted manufacturer is not so easy and need a deep research, Hong xing et al (2015). Besides, be aware of the guarantee that given by OEM to their product. Any offense can increase the cost. If company still buy spare from OEM, another method shall be choose to decrease the cost such as buy directly from OEM. This is because most of the company are buying the parts with the third party and it costly more that direct buying. Use all power as the customer to negotiate with OEM.

Obsolete parts are one of the common problem facing by a company. Any errors, lost in sales, miscalculations and unexpected changes in the product life cycle are assured to take their cost. Most of the companies will end up with warehouses disorderly with non-moving spares and scrapping which can generates a huge cost inform of inventory’s space, unusable logistic arrangements and administration that can worth thousands of stock every year, Kurt (2016). By putting it on a single place to be prune out can decrease loses. As have been mention in 2.2, slow moving spare parts have their pros and cons. However, there are some spares that not moving at all in a year. This can be avoided by separating them into several sections such as necessary, adequate and inadequate. By this method, store keeper can analyze the unwanted spare and this indirectly will eliminate the unnecessary spares, Maria Elena et al (2013).

As the number of spare part is directly proportional with the space required to store the spares, it is better if the company interweave some of the suppliers to be the consignment stockist for the company. Consignment stockist means that the supplier hold the buying items as their inventory and take a good care of it and if the company no longer need it so that spare can be sold to the supplier, Metso (2015). This is one of the best method because of the relationship between supplier and company will be closer and the supplier will take a good care on the spares in term of company as a regular customer. A Pareto analysis will be conducted to optimize spare parts management. The explanation about Pareto analysis will be discuss on the methodology in this paper.

2.7 Reliability, Availability and Maintainability

Reliability, maintainability, and availability (RAM) are three systems attributes that are of great interest to systems engineers, logisticians, and users. Together, they affect both the utility and the life-cycle costs of a product or system. The origins of current reliability engineering can be traced. The most concern parts were on the electronic and mechanical components, Ebeling (2010).

Failure is the normal things that occur on a machine. This failure can be controlled by performing a good maintenance strategy. There are three types of maintenance which are preventive maintenance, predictive maintenance and corrective maintenance. Preventive maintenance is maintenance that conduced before the failure occur. As example the replacement of engine oil every 10,000 km or 3 month (which one come first) was conducted to prevent the engine from failure. Where predictive maintenance is a maintenance that conducted to estimate the lifetime of a machine such as condition based monitoring (CBM). Corrective maintenance is the maintenance that conducted after the machine failure (usually on non-critical machinery). By choosing the best strategy for maintenance, indirectly will increase the maintainability of a machine. Maintainability is defined as the probability of performing a successful repair action within a given time. In other words, maintainability measures the ease and speed which a system can be returned to the operational status after the failure occurs, ReliaSoft (2016).

Reliability is defined as the possibility of a system or element in a system performing intended function under a stated conditions without any failure for a given period of time, ASQ (2011). This reliability must include a detailed description on function, environment, time scale and cause of failure. The data collected must be accurate from source otherwise it will affect the whole analysis. There are two source of measurement error which are random and systematic. Random error is individual fluctuation that cause by human mistake while systematic error is due to the test itself and more on equipment error.

Availability is probability that a repairable system or system element is operational at a given point in a time under a specified set of environmental conditions. Availability depends on reliability and maintainability and it is discussed in detail later in this topic, ASQ (2011). A failure is the event, or impracticable state, in which any item or amount of an item does not, or would not, perform as their specified. The failure mechanism is the physical, electrical, chemical, thermal, or other process that results in failure, GEIA (2008). Availability of a system is naturally measured as a factor of its reliability. When the reliability increases the availability is also increase. Availability of a system can also be increased by the strategy on increasing the testability, maintainability and diagnostics. Increasing the maintainability during early design phase is generally easier compare to reliability, testability and diagnostics. Maintainability estimates the item to repair by their replacement rates which are also generally more accurate. However, because the doubts in the reliability estimates and the diagnostic times are in most large case, it is more expected to dominate the availability and the prediction problem, even the maintainability levels are very high.

Optimizing spare part on a plant can decrease the time for maintenance. By lowering the time for maintenance, the reliability, availability and maintainability of a plant can be increase. This indirectly will increase the productivity of a plant and the plant profit.

2.8 MTBF, MTTR, and MTTF

MTBF, MTTR, and MTTF are reliability terms based on methods and procedures for develop predictions of a product. Companies are often need to know the reliability of a production to obtain, use or invest into a product. MTBF (Mean Time Between Failure), MTTR (Mean Time To Repair), and MTTF (Mean Time To Failure) are the ways to show a numeric value based on a collecting of data. This data can quantify the rate of failure and also the time of the expected performance. The numeric rate also can be expressed as any measure of time, usually hours (Susan Stanley, 2011).

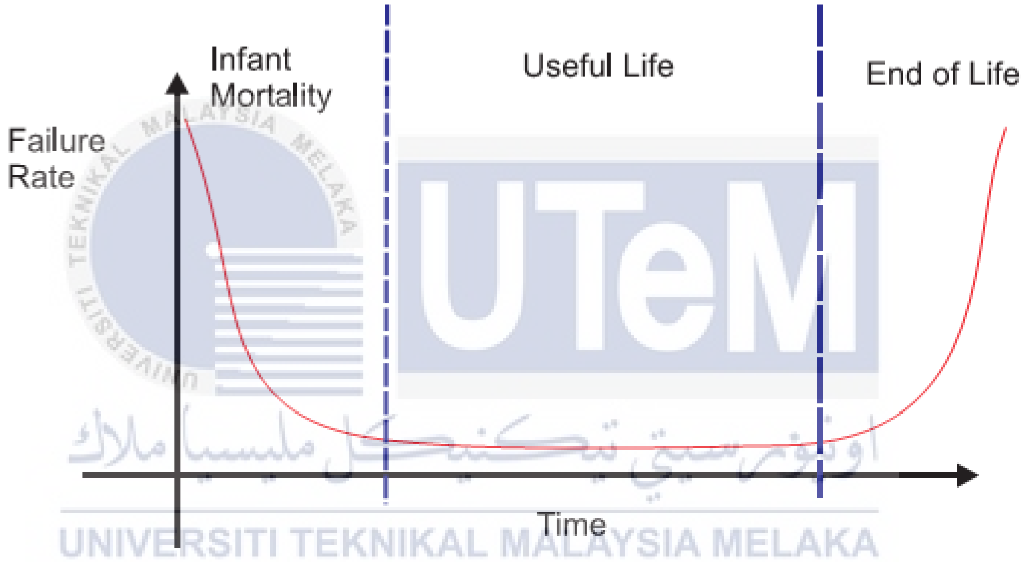

Figure 2.8.1: Bathtub curve

Mean Time Between Failure (MTBF) is a term that used to provide an amount of failures per hours for a production and it is a measure on how reliable the equipment is. This is the most common analysis about the life span of a product. Furthermore, this is important in the decision-making process of the finale user. MTBF is more important for industries and investors than for the consumers. Most consumers are determined the price and will not take MTBF into their attention although the data often readily offered. On the other hand, when a equipment such as media converters or the switches must be installed into critical applications, MTBF will becomes very important. In addition, MTBF may be an expected line item in the request for quote (RFQ). Without a proper data, the manufacturer's equipment would be immediately eliminated.

Mean Time To Repair (MTTR) is the time needed for repair when the failure occur. In operational system, repair generally give a meaning by replacing a failed hardware part. Therefore, hardware MTTR could be observed as the mean time for replace a failed hardware component. By taking too long time to repair, the production will be struggled by the cost of the installation for the long run due to time taken from a down time until the new part attains and the probable window for the time required to schedule the installation. Therefore, to avoid a high MTTR, usually many companies are keeping the spare products so that a replacement can be installed quickly. However, the customers will inquire about reversal the time of repairing a product and indirectly it can fall into the MTTR classification.

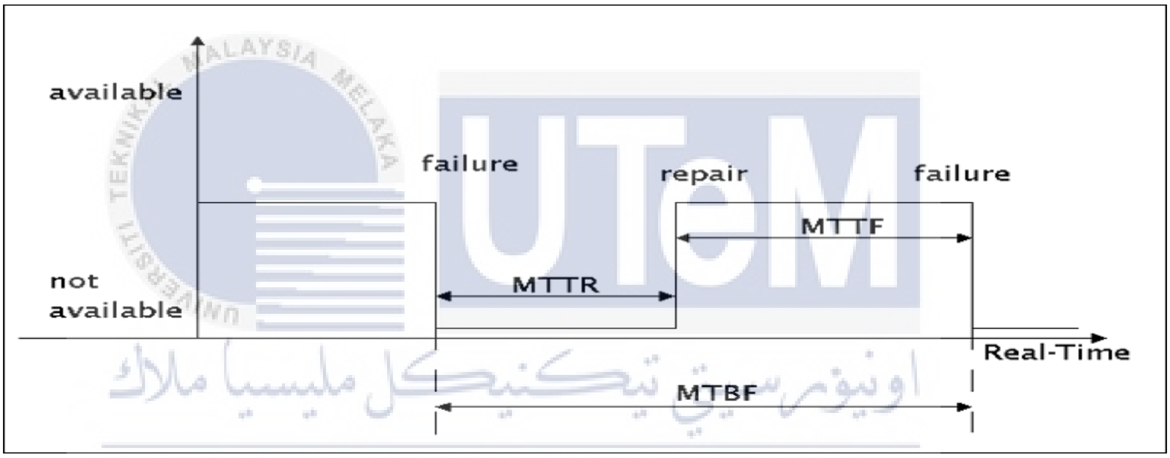

Figure 2.8.2: Availability versus real time graph. (Susan Stanley, 2011)

Mean Time To Failure (MTTF) is a basic measure of reliability for unrepairable systems. It is the mean time estimated until the first failure on the piece of an equipment occur. MTTF is a numerical value and it is intended to be a mean over the long period of time and a large number of units. Theoretically, MTBF should be used only on referencing to the repairable item while the MTTF must be used for non-repairable items. But, MTBF is usually used for both which are repairable and non-repairable items.

2.9 Calculations and Formulas

Availability is the percentage of time on the availability of the equipment for production, after all schedule and unscheduled downtime. The higher the availability of a machine, the better the production. The formula can be express as:

$$Availability = \frac{Total\ time - Downtime}{Total\ time} \text{ .... eq. 1}$$

Where:

Total time = Hours of production usualy a year which is 8760 hours.

Downtime = The time from the machine fail until it operate normally (hour).

Mean Time To Failure (MTTF) is the measurement of total running of a machine before it fail. Higher is better.

$$MTTF = \frac{Total\ time - Downtime - Nonused\ time}{Number\ of\ breakdown} \text{ .... eq. 2}$$

Where:

Non-used = The time that have not been used for any activity.

Mean Time To Repair (MTTR) average time taken for repair the equipment or machine to be operate again. Lower is beter.

$$MTTR = \frac{Unscheduled\ Downtime}{Number\ of\ breakdown} \text{ .... eq. 3}$$

Where:

Unscheduled downtime = Period when the unprepared failure occur (hour).

Number of breakdown = Total number of machine failure occur.

Mean Time Between Failures (MTBF) is defined as the ability of an item to perform a require function under the stated conditions for a period of time. Higher is better.

$$MTBF = \frac{Total\ Operating\ Time\ x\ Population\ of\ Equipment}{Number\ of\ Observed\ Failures} \text{ .... eq. 4}$$

Where:

Total operating time = Total operating time of the machine (hour)

Population of equipment = The number of equipment that operate in a selected area

Number of observed failures = Total equipment failures in the selected area

Material usage per work orders measures the effectively the materials are being acquired and used. Lower is better which indicate the material use is optimum.

$$Material\ usage\ = \frac{Total\ material\ charged\ to\ work\ order\ (RM)}{Number\ of\ work\ orders} \text{.........} \text{ eq. 5}$$

Where:

Total material charged to work order = Total cost for complete the work (RM)

Number of work order = Total number of work orders requested

Maintenance cost index is the percentage of total production cost which indicates the overall effectiveness of resource use. Lower is better as the maintenance cost must be lower than production cost.

$$Maintenance\ cost\ index = \frac{Total\ maintenance\ cost\ \ (RM)}{Total\ production\ cost\ (RM)} \text{..............} \text{ eq. 6}$$

Where:

Total maintenance cost = Total cost for the maintenance to complete (RM)

Total production cost = Total cost to complete the production (RM)

Planning and scheduling index is the time spent on a planned and scheduled tasks over the total time measures. This index will show the effectiveness of the organization and maintenance planning activities. Lower is better as the time planned and scheduled lower than the total time which means it more effective.

$$Planning\ and\ scheduling\ index = \frac{Time\ Planned\ and\ Scheduled}{Total\ time} \text{...} \text{ eq. 7}$$

Where:

Time planned and scheduled = the planned time (hours)

Total time = number of employee multiple with working hours

Cost of breakdown production lost is the percentage of breakdown cost over the total of direct cost. Lower is better as the percentage of production loss is low.

$$Breakdown\ production\ lost = \frac{a\ x\ (b+c)}{d} \text{................................ eq. 8}$$

Where:

a = Breakdown hours

b = Cost of production lost per time

c = Maintenance cost of breakdown per time

d = Total direct cost

Maintenance cost versus the cost of the asset base. This measures how effectively the maintenance department manages to repair and maintain the overall asset base. Lower is better as the maintenance cost be more effective.

$$Direct\ maint.cost\ effectiveness = \frac{Total\ direct\ maintenance\ cost}{Asset\ value\ (Replacement\ cost)} \text{....eq. 9}$$

Where:

Total direct maintenance cost = Total cost for maintenance on a selected asset

Asset value (replacement cost) = Cost if the selected asset is replace

Stores turnover calculation can measure the effectiveness of the inventory to support the maintenance. Lower is better.

$$Inventory\ turnover = \frac{Cost\ of\ issues}{Inventory\ value} \text{................................... eq. 10}$$

$$Inventory\ turnover\ index = \frac{Inventory\ value\ this\ year}{Inventory\ value\ last\ year} \text{................ eq. 11}$$

Where:

Cost of issues = The cost for the material issued (RM)

Inventory value = The value of the spares

Inventory value this year over last year = diff. between the price by a year (RM)

Stock out is one of the most contentious areas. It will reflecting the finance, which wants to minimize inventory and the operations. It also maintain the output needs for spares to support it. Lower is better as the financial being more effective.

$$Stock\ issue\ index\ = \frac{Stock\ issue\ this\ year}{Stock\ issue\ last\ year} \text{..............................} \text{ eq. 12}$$

Where:

Stock out this year = total spares that have been used this year

Stock out last year = total spares that have been used last year

Work order accuracy measures how closely the planning process from work request to job completion matches the reality. This also can optimize the number of spare parts need to the company. Lower is better. It indicates the planning process is matches the reality.

$$Work\ order\ accuracy\ = 1 - \frac{Number\ of\ work\ order\ completed}{Number\ of\ work\ Errors\ identified} \text{..........} \text{ eq. 13}$$

Where:

Number of work order completed = Total works order that have been completed by the workers

Number of work errors identified = total errors on working that have been identified

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will describes the methodology on the fieldwork platform that will be conducted in this project. The flow chart of the project is shown in **Figure 3.1**. This project starts by studying the methods for optimizing the spare parts and to study the correct way to obtain the correct and valid measurement data. After suspected loss cause by spares management of the plant was identified, a survey, some interviews and observation will be performed. If the mean time to repair do not show a significant result, a solution will be proposed to optimize the spare parts. Otherwise a new suspected loss source is investigated, a new observation is prepared and a new measurement is taken for the input of spares optimization.

3.2 Qualitative Research

Although it is possible, it not necessary to collect the data from everyone in the plant in order to get a valid results. Therefore, in this paper, the researcher collects the data from maintenance workers that only be assigned at maintenance department in the plant. There are several types of qualitative sampling that can be used. First is purposive sampling. Purposive sampling is a group of staff that have been selected by criteria that relevant to the research. In this case, the sample size is fixed prior to the data collection and it is depend on the time available and resources. Second sampling method is quota sampling. This type of sampling is much similar to the first method which have the same sample size but more specific on their characteristic. The staff have been divided by their experience and expertise to calculate the mean time to repair a machine. This method will include the best time for repair and more accurate data can be collected. The last method of sampling that may be used is snowball sampling. Snowball sampling is sample that obtained from external people who have been worked with the company such as contractors. This data is very important because some of the tasks in the plant were done by the contractors. However, all of the methods are related to each other and by using all the methods, more accurate qualitative data can be collected.

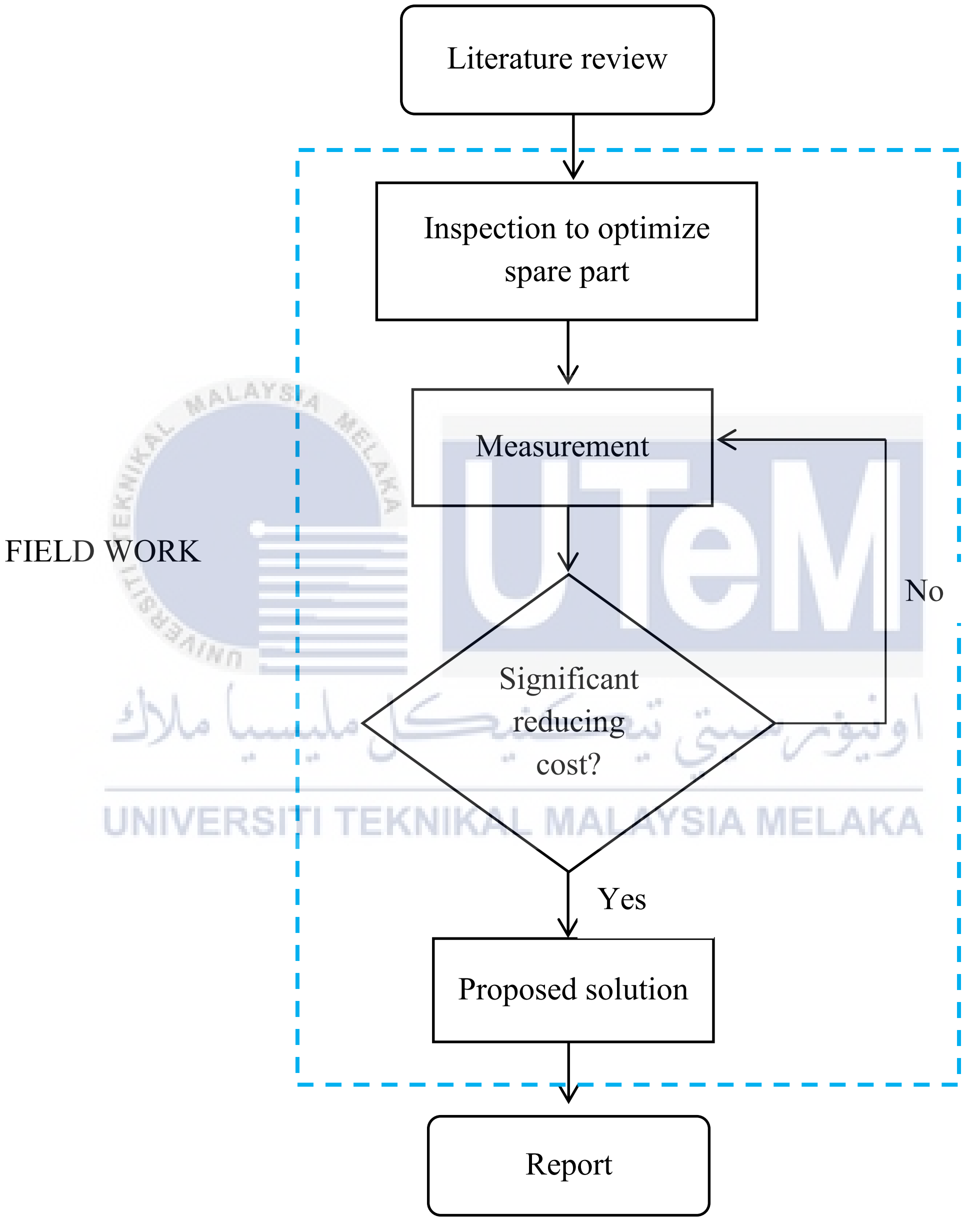

Figure 3.1: Flow chart of the methodology

3.2.1 Qualitative research interview

McNamara (1999) state that interviews are mostly useful for receiving the story behind a contributor experiences. One of a method to get the data is by interviews. Interviews will be completed by researcher on what the interviewee answer. Furthermore, interview is more in personal compare to questionnaire and personal interview will work directly with respondent. There are four type of interviews. First is informal conversation interview. Informal conversational interview is where no pre-set questions are being asked. Additionally, as to remain the interview as adaptable and open, interviewer will just follow the flow informally. This method can increase the relationship between interviewer and respondent. As the respondent being more comfort with the interviewer, the more information can be gather along the session.

Second type is general guide approach interview. This type intended to make sure that all the collected information have a same general areas to each interviewee. This method also can ensure the validity of the information. Some repeated answer will ensure more accurate the data is. Third type is standardized of the open-ended interview. This is the type where required a same open-ended questions will be inquire to the all interviewee. By conducting this method, more time can be saved and the interviews can be more easily analysed and compared. Last method is closed fixed response interview which is the interviewee will be asked a set of similar question to each other. This method the most systematic method can be used. This is because by asking the same question to the workers, the time required will be reduced. This format is very useful for anyone that not practice in interviewing.

Before conducting any interview, it is very importance for researcher to rehearse and organise detailed the interview. Interviewer need to know more about how and what the point that need to be asked before conducting the interview. Furthermore, interviewer should have a list to ask based on the background of the research and describe all the entire study. So the respondent or interviewee will easy to understand and answer all the questions. Besides that, interviewer need a deep study on their topic to make sure all the misunderstanding while conducting the interview can be clear. The interviewee may be wonder why the question is being ask to them. Researcher should avoid bias while conducting the interview. This is because all the informations that obtain must be accurate and the incorrect data will lead to unsatisfied result. By oblique the result, researcher might jeopardize the finding and the purpose of study.

To conduct the interview, the interviewer need some preparation. Firstly, choose a least distraction place so that the interviewee will be more focus when they are being interview. This is important for interviewee to recall the informations and indirectly can save the time for interviewing. Besides that, briefly explain the purpose of the research to the participant to increase their understanding. Then, address the confidentiality terms to them as if the respondent want to not be known or the information is very confidential. In addition, researcher also need to explain the time needed to complete the interview. This is for indicate a comfort zone for the interviewee because if the interviewee in rush, the potential to get incomplete information will increase. Provide some contact information to interviewee so they can contact if any update have been done. If there any doubts while conducting the interview, allow them to clarify it. Furthermore, researcher need to prepare a method for collect the data such as take notes and record the session, Dapzury et all (2002).

Inform of getting a good interview session, there are some criteria for a qualification as an interviewer. A good interviewer will being familiar on the topic that cover in the interview. Then, outline all the procedure of the session so that the interview will be run smoothly. Be clear and gentle on answering and asking when speak to the respondent. This is because to prepare a harmony and comfort atmosphere for the interviewee. Researcher need to be a lead in the conversation. Consequently the interview will still in topic and no time will be waste. The researcher should capable to interpret the information so that the respondent will be more confident to continue the session.

By conducting the interview, a quantitative result can be obtain to be use in the calculation. Figure 3.2.1 show the stages that must be follow in this method to get an accurate and valid data. Therefore, by collecting all the data the calculation and analysis can be perform to obtain the possible solutions that can be done inform of optimizing the spares. All the planning and question must be arranged first to obtain a smooth and correct method. Unprepared interviewing will result a bad consequent such as lack of information, incorrect result or worst is respondent refuse to give any information.

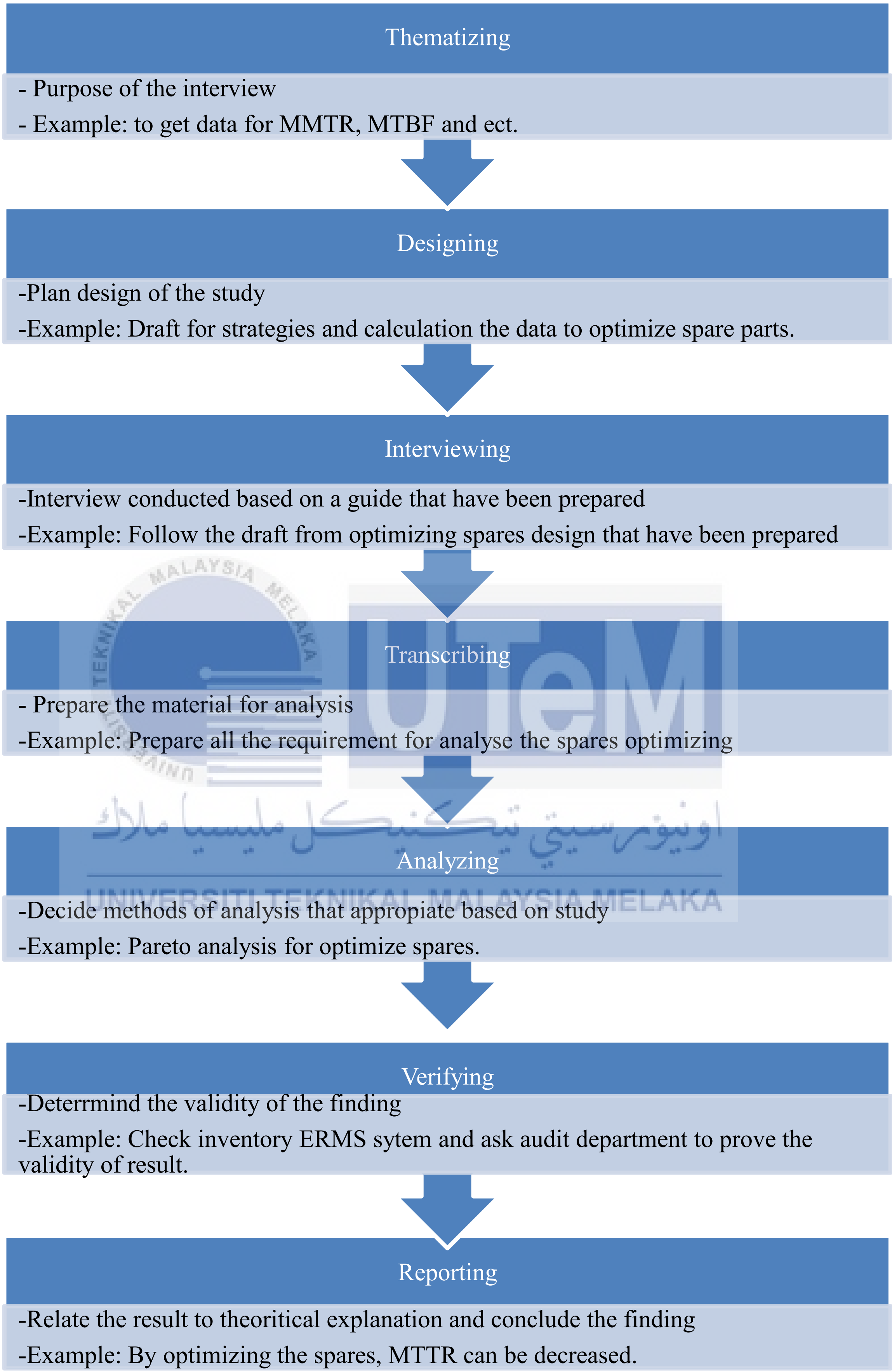

Figure 3.2: Interview investigation stages

3.3 Pareto Analysis

Pareto analysis is a statistical method that is used for selecting the limited tasks amount and produce a substantial total effect. It uses the Pareto Principle or recognised as 80-20 rule as the impression is by doing the 20 percent of work, it can generate 80 percent of the overall work advantage. In other words, in a majority of the problems which are 80%, there are only several key causes that produce the problems which is 20%. Pareto analysis have been used in most of the company to reduce the main causes in a problem. The major problem maybe a few but it can result a big lost that must be facing by the company, Aniruddha Joshi et al (2014).

By performing this analysis, several of the major problem can be separated from many possible problems. Therefore, workers can be more focus on improvement of the plant. Furthermore, this analysis also required an arrangement of data according the importance or priority toward the problems. So the data will be more systematic and easy to read as the arrangement is more readable. In addition, by doing this analysis we also can regulate which problems are more important by using the data and with no perceptions.

Pareto analysis can be used in designing the optimization of spares in order to identify the loss, error, faults and causes of excessive cost. This analysis help researcher to be focus on the main problems that are very important only. This analysis is very useful on priority establishing by show only on the most critical causes to be tackled. By eliminating only the main causes, generally is more helpful for the workers to focus on their job than solve the problems one by one. Furthermore, by successfully achieve the analysis requirement, the company also can decease the cost for spares as the main cause of the problems was eliminated.

The consequent by doing the analysis is the efforts can be focused on the most common causes. Besides that, the analysis also can be perform on a fix interval of time because the data is static. There are several step that must be followed to create a good Pareto analysis result. Figure 3.3 will show how to conduct a complete Pareto analysis.

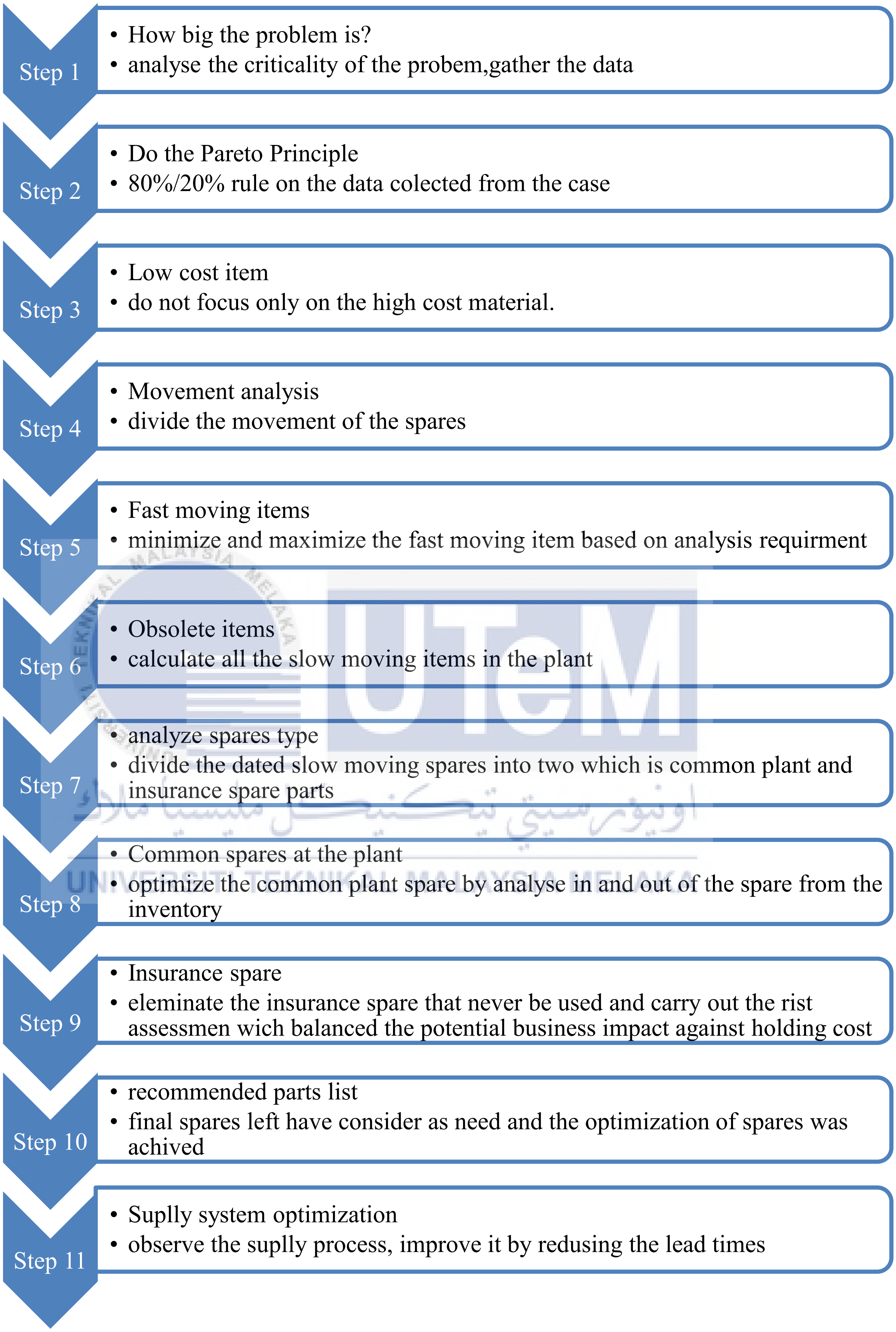

Figure 3.3: Steps to optimize spares

CHAPTER 4
RESULTS AND ANALYSIS

4.1 PRELIMINARY RESULTS

4.1.1 Pareto Analysis for Valve Spare Parts

Table 4.1 shows the list of spares issued last year by boiler maintenance section to the management. Initially, the total price of the spares was measured to decide the arrangement of spares based on their priority. The list is then created in Microsoft excel software depending on the number and price of the spares. Cumulative amount and cumulative percentage were added to differentiate the significant and the value, from highest to the lowest value.

In this case a total list of 56 spares were included for analysis. It is important to properly mark up and label all the points according to the Pareto steps. The list is then converted into a chart which is called as Pareto chart. The chart will be covered at **Section 4.1.2** in this report. There is no limit to the points to be taken because the data was real and it is based on the spares issued by the company. The more the number of spares, the more range of data created indirectly which will increase the total cost. Pareto analysis is one of the way for identifying the cause of a problem for which in this case is the cost of the valve's spares from boiler section.

Table 4.1: List of Spares and Their Price

No	Items	Total (RM)	Cumulative Amount	Cumulative %
1	Complete Set Motorised Paralle Slide Gate Valve (Without Actuator)	968,688.00	968,688.00	14.58
2	Complete Set Motorised Globe Valv (Without Actuator)	590,409.00	1,559,097.00	23.47
3	Complete Set Motorised Glob Valve (Without Actuator)	481,261.80	2,040,358.80	30.71
4	Pressure Seal Bonnet : A350 LF2 + Stellite	391,555.20	2,431,914.00	36.61
5	Pressure Seal Bonnet A105/A350LF2 + STELLITE	379,485.60	2,811,399.60	42.32
6	Complete Set Motorised Globe Valve (Without Actuator)- HAC 40	342,636.00	3,154,035.60	47.47
7	Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	295,728.00	3,449,763.60	51.93
8	Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	199,017.00	3,648,780.60	54.92
9	Complete Set Motorised Globe Valve (Without Actuator)	180,913.80	3,829,694.40	57.64
10	Complete Set Motorised Globe Valve	174,352.80	4,004,047.20	60.27
11	Dics: A 350 LF2 + STELLITE	171,477.70	4,175,524.90	62.85
12	Complete Set Motorised Globe Valve (Without Actuator) -flange	170,059.80	4,345,584.70	65.41
13	Complete Set Motorised Globe Valve (Without Actuator)	167,760.00	4,513,344.70	67.93
14	complete set motorised globe valve (without actuator) A 105	153,778.80	4,667,123.50	70.25
15	Dics: A105/A350LF2 + STELLITE	149,809.80	4,816,933.30	72.50

16	Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	146,772.00	4,963,705.30	74.71
17	Complete Set Motorised Globe Valve (Without Actuator)	130,800.00	5,094,505.30	76.68
18	Dics: A 350 LF2 + STELLITE for 3"	115,951.80	5,210,457.10	78.43
19	Complete Set Motorised Globe Valve (Without Actuator)	105,480.00	5,315,937.10	80.02
20	Stem: AISI 431	101,145.60	5,417,082.70	81.54
21	Pressure Seal : Graphite	81,226.80	5,498,309.50	82.76
22	Pressure Seal : Graphite	77,714.40	5,576,023.90	83.93
23	Dics: A 479 304L + STELLITE, Stem: AISI 431 and Disc Nut : A 479 304L	77,137.80	5,653,161.70	85.09
24	Gasket : Graphite for 3"	71,280.00	5,724,441.70	86.16
25	Stem: AISI 431	70,248.60	5,794,690.30	87.22
26	Dics: A 479 304L + STELL with Stem: A 479.410.3	68,850.00	5,863,540.30	88.26
27	Dics: Steel A 105 / Stellite with Stem: Stainless Steel A 564 Type 632	62,856.00	5,926,396.30	89.20
28	Dics: Steel A 105 / Stellite with Stem: Stainless Steel A 564 Type 632	62,856.00	5,989,252.30	90.15
29	Stem: AISI 431 for 3"	56,636.40	6,045,888.70	91.00
30	Complete Set Motorised Globe Valve (Without Actuator)-HAH 20	53,100.00	6,098,988.70	91.80
31	Pressure Seal: AISI 316 For 2" Valve	42,240.00	6,141,228.70	92.44
32	Pressure Seal Cover: AISI 420 For 1" valve	40,800.00	6,182,028.70	93.05
33	Complete Set Motorised Globe	38,400.00	6,220,428.70	93.63

	Valve (Without Actuator)-HAJ 03			
34	Pressure Seal: AISI 316	35,520.00	6,255,948.70	94.16
35	Pressure Seal Cover: AISI 420	35,280.00	6,291,228.70	94.70
36	Lock Nut : A 540 B 2, Thrust Disc : A 314 GR 440C And Graphite gasket : 9593-6	29,712.00	6,320,940.70	95.14
37	Dics: AISI420/ Stellite For 2" Valve	25,980.00	6,346,920.70	95.53
38	Stem: ASTM A182 F6	25,980.00	6,372,900.70	95.92
39	Pressure Seal : AISI 316 -HAH 20	20,880.00	6,393,780.70	96.24
40	Dics: AISI316+St	19,080.00	6,412,860.70	96.53
41	Stem: ASTM A182 F6	18,840.00	6,431,700.70	96.81
42	Dics: AISI420+St	18,720.00	6,450,420.70	97.09
43	Stem: AISI316	18,600.00	6,469,020.70	97.37
44	Pressure Seal: AISI 316 For 1" valve	16,776.00	6,485,796.70	97.62
45	Pressure Seal Bonnet: ASTM A105N	15,840.00	6,501,636.70	97.86
46	Graphite Gasket Material : 9593-6	15,069.60	6,516,706.30	98.09
47	Lock Nut : A 540 B 22, Thrust Disc : A 314 GR 440C and Graphite gasket : 9593-6	15,069.60	6,531,775.90	98.32
48	Lock Nut : A 540 B 22, Thrust Disc A 314 GR 440C and Graphite gasket	15,069.60	6,546,845.50	98.54
49	Body/Bonnet Gasket: Graphite	14,742.00	6,561,587.50	98.76
50	Body/Bonnet Gasket: Graphite	14,742.00	6,576,329.50	98.99
51	Bonnet Gasket : AISI316	12,960.00	6,589,289.50	99.18
52	Dics: AISI420+St -HAH 20	12,960.00	6,602,249.50	99.38
53	Stem: ASTM A182 F6 -HAH 20	12,960.00	6,615,209.50	99.57
54	Dics: AISI420/STELLITE	10,320.00	6,625,529.50	99.73
55	Stem: AISI416	10,320.00	6,635,849.50	99.88
56	Pressure Seal Cover : ASTM A182 F6	7,800.00	6,643,649.50	100.00
	TOTAL	RM6,643,649.50		

4.1.2 Pareto Chart

Figure 4.1 shows the Pareto chart that is based on the list in **Table 4.1**. This chart helps to identify the items that need to be addressed. The value of the Pareto Principle for this case will remind researcher to focus on the 80% value of things that matter. This is because from all of the items, some of them are really important. Those items will produce approximately 80% of the total cost of the spares. Therefore, by identifying and focusing on those things first, it will be easier for the researcher to decrease the cost of the spares. A Pareto chart is a graphical representation that displays data in order of priority

Based on the chart, the quantity of items in 80% value chart area is lower than the items in 20% value chart area. However, if the reseacher decrease only 10 percent from the 80% value chart area the value is 8% from the total cost compared to 10 percent from the 20% value chart area which is only 2% of the total cost. As the conclusion, the area that need to be focusing on is the 80% value chart area and optimize the number of items in that area so that the cost of the spares can be minimized.

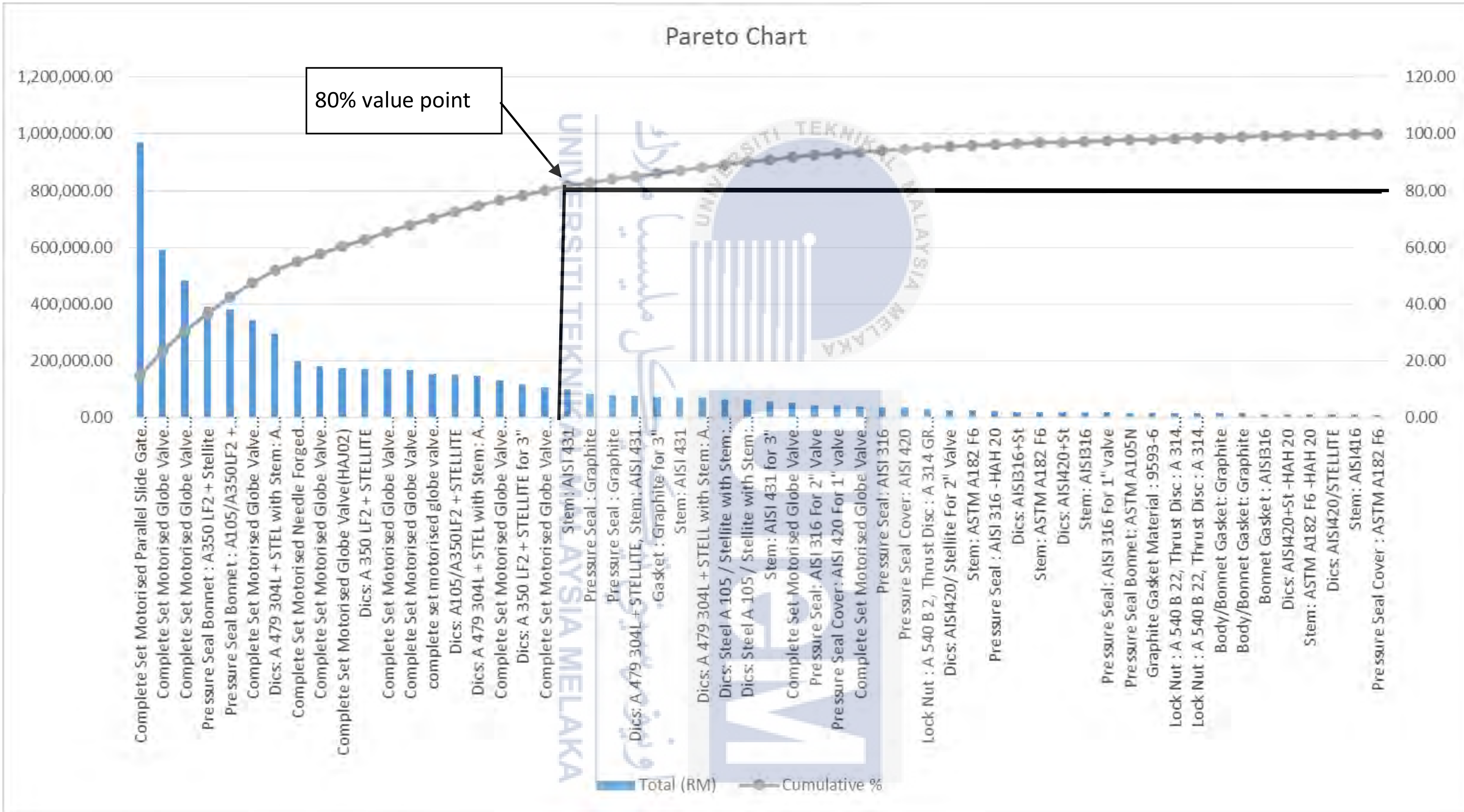

Figure 4.1: Pareto chart

4.1.2 The Recommended Spares for Optimization

Based on the Pareto analysis, a list of 19 items that needs to be focused on had been tabulated as shown as **Table 4.2**. From 56 items, 19 of them carried 80 percent of the total value. Therefore, by focusing on the smaller list, it will be easier for researcher to do the analysis and evaluation in order to get optimize numbers of spare. Furthermore, with help from engineers, foremen, contractors and access to Electronic Record Management System (ERMS), researcher can gather the information of the spares from the past three years and had been tabulated in **Table 4.2.** The results will be used by researcher for the further analysis in this paper.

Table 4.2: Recommended Spares for Optimization.

No.	Items	Unit Price (RM)	Total (RM)	Cumulative Amount	Cumulative %
1	Complete Set Motorised Parallel Slide Gate Valve (Without Actuator)(3")	80,724.00	968,688.00	968,688.00	14.58
2	Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	98,401.50	590,409.00	1,559,097.00	23.47
3	Complete Set Motorised Globe Valve (Without Actuator)(3")(HAC60))	80,210.30	481,261.80	2,040,358.80	30.71
4	Pressure Seal Bonnet : A350 LF2 + Stellite	16,314.80	391,555.20	2,431,914.00	36.61
5	Pressure Seal Bonnet : A105/A350LF2 + STELLITE	31,623.80	379,485.60	2,811,399.60	42.32
6	Complete Set Motorised	28,553.00	342,636.00	3,154,035.60	47.47

	Globe Valve (Without Actuator)- HAC 40				
7	Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	12,322.00	295,728.00	3,449,763.60	51.93
8	Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	33,169.50	199,017.00	3,648,780.60	54.92
9	Complete Set Motorised Globe Valve (Without Actuator)(HAC60)	30,152.30	180,913.80	3,829,694.40	57.64
10	Complete Set Motorised Globe Valve(HAJ02)	29,058.80	174,352.80	4,004,047.20	60.27
11	Dics: A 350 LF2 + STELLITE	14,289.80	171,477.70	4,175,524.90	62.85
12	Complete Set Motorised Globe Valve (Without Actuator) -flange	28,343.30	170,059.80	4,345,584.70	65.41
13	Complete Set Motorised Globe Valve (Without Actuator)(1")(HAH92)	13,980.00	167,760.00	4,513,344.70	67.93
14	complete set motorised globe valve (without actuator) A 105	25,629.80	153,778.80	4,667,123.50	70.25
15	Dics: A105/A350LF2 + STELLITE	24,968.30	149,809.80	4,816,933.30	72.50
16	Dics: A 479 304L + STEL with Stem: A 479.410.3 and	12,231.00	146,772.00	4,963,705.30	74.71

	Disc Nut : A 479 304L				
17	Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	10,900.00	130,800.00	5,094,505.30	76.68
18	Dics: A 350 LF2 + STELLITE for 3"	19,325.30	115,951.80	5,210,457.10	78.43
19	Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	8,790.00	105,480.00	5,315,937.10	80.02

4.2 High Cost and Low Cost Items

In order to optimize the spares, all the items must be divide into two section which are high cost item and low cost item. This is conducted in order to locate which items that needs priorities on more. Furthermore, if the spare that have a high value be optimised, automatically the cost for issuing will decrease higher than low cost but not all high cost item can be optimize. Therefore, the spares need to be analysed briefly and give the priority more to the high cost items in order to maximize the value that can be decrease.

In addition, to divide the costing into two different parts, the median value was used and the value is RM 25,629.80. Therefore;

high cost item ≥ 25,629.80
low cost item <25,629.80

Table 4.2.1: High cost and low cost items

Items	Quantity	Unit Price (RM)	Total (RM)	Cumulative Amount	Cumulative Amount Cumulative %
Complete Set Motorised Parallel Slide Gate Valve (Without Actuator)(3")	12	80,724.00	968,688.00	968,688.00	14.58
Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	6	98,401.50	590,409.00	1,559,097.00	23.47
Complete Set Motorised Globe Valve (Without Actuator)(3")(HAC60))	6	80,210.30	481,261.80	2,040,358.80	30.71
Pressure Seal Bonnet : A350 LF2 + Stellite	24	16,314.80	391,555.20	2,431,914.00	36.61
Pressure Seal Bonnet : A105/A350LF2 + STELLITE	12	31,623.80	379,485.60	2,811,399.60	42.32
Complete Set Motorised Globe Valve (Without Actuator)- HAC 40	12	28,553.00	342,636.00	3,154,035.60	47.47
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	24	12,322.00	295,728.00	3,449,763.60	51.93
Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	6	33,169.50	199,017.00	3,648,780.60	54.92
Complete Set Motorised Globe Valve (Without Actuator)(HAC60)	6	30,152.30	180,913.80	3,829,694.40	57.64
Complete Set Motorised Globe Valve(HAJ02)	6	29,058.80	174,352.80	4,004,047.20	60.27
Dics: A 350 LF2 + STELLITE	12	14,289.80	171,477.70	4,175,524.90	62.85
Complete Set Motorised Globe Valve (Without Actuator) -flange	6	28,343.30	170,059.80	4,345,584.70	65.41
Complete Set Motorised Globe Valve (Without Actuator)(1")(HAH92)	12	13,980.00	167,760.00	4,513,344.70	67.93
complete set motorised globe valve (without actuator) A 105	6	25,629.80	153,778.80	4,667,123.50	70.25
Dics: A105/A350LF2 + STELLITE	6	24,968.30	149,809.80	4,816,933.30	72.50
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	12	12,231.00	146,772.00	4,963,705.30	74.71
Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	12	10,900.00	130,800.00	5,094,505.30	76.68

Dics: A 350 LF2 + STELLITE for 3"	6	19,325.30	115,951.80	5,210,457.10	78.43
Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	12	8,790.00	105,480.00	5,315,937.10	80.02

From the **Table 4.2.1**, there are five items which have high value and need to be focused first. However the low cost item also need to be analysed too in order to optimise the spares. From the ten items, all high cost item needs to be optimized. This is due to the trend of the failure among the high cost item. Based on this trend, researcher can do the forecast for the next year by calculating the mean of the failure.

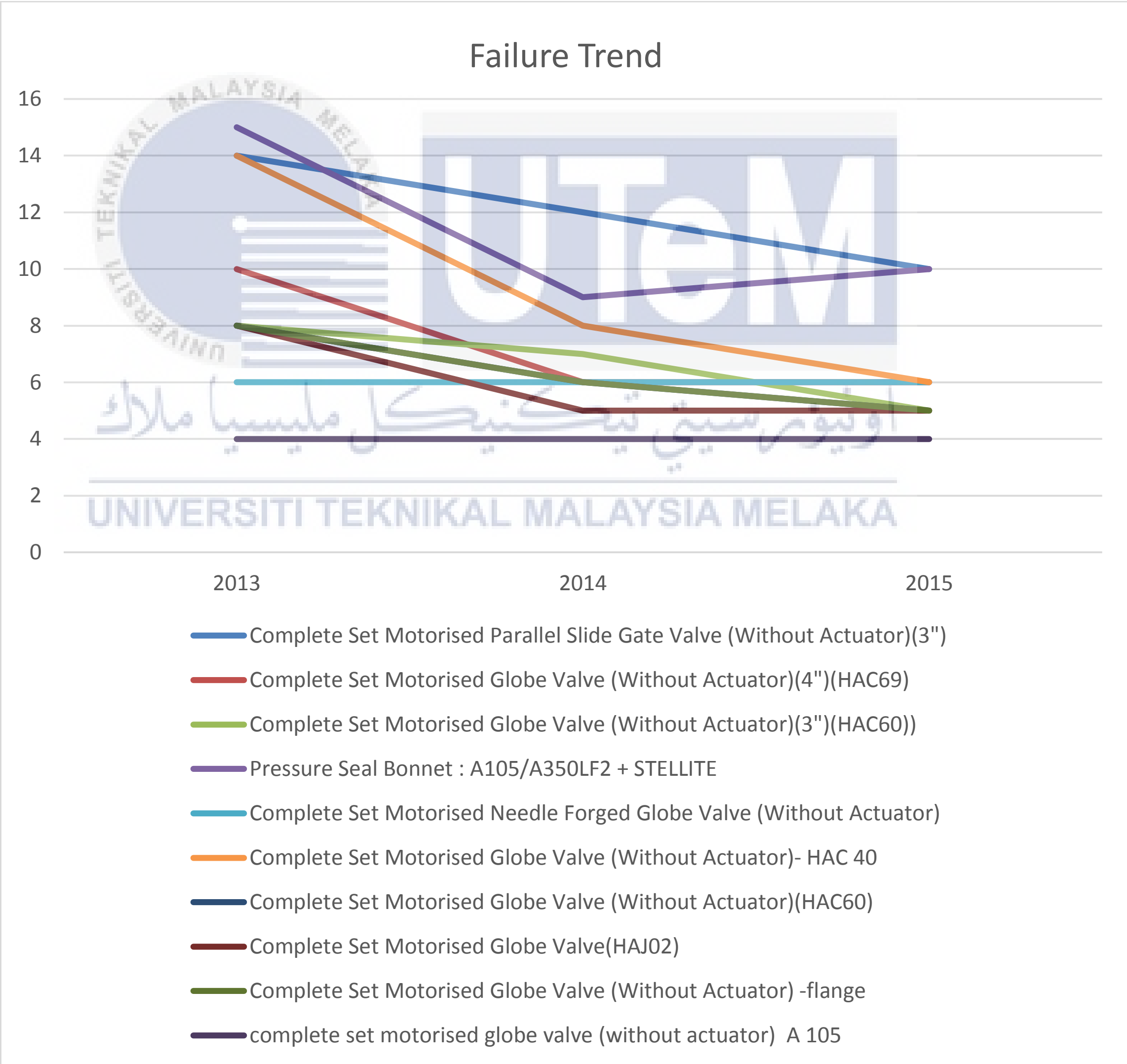

Figure 4.2: Failure trend for high cost spares

Table 4.2.2: Failure forecasting for high cost items

Items	Failure by Year			Failure Approximation (mean)
	2013	2014	2015	
Complete Set Motorised Parallel Slide Gate Valve (Without Actuator)(3")	14	12	10	12
Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	10	6	6	7
Complete Set Motorised Globe Valve (Without Actuator)(3")(HAC60))	8	7	5	7
Pressure Seal Bonnet : A105/A350LF2 + STELLITE	15	9	10	11
Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	6	6	6	6
Complete Set Motorised Globe Valve (Without Actuator)-HAC 40	14	8	6	10
Complete Set Motorised Globe Valve (Without Actuator)(HAC60)	8	6	5	6
Complete Set Motorised Globe Valve(HAJ02)	8	5	5	6
Complete Set Motorised Globe Valve (Without Actuator) - flange	8	6	5	6
complete set motorised globe valve (without actuator) A 105	4	4	4	4

After that, the remaining spare in the inventory need to be analysed. From **Table 4.2.3**, the remaining of the spares for the high cost item is still brand new and can operate perfectly. By completing the remaining item first, company can decrease the number of spare issue for the next year. After analysing the data, a list of optimised spares for high cost item was tabulated in **Table 4.2.4**.

Table 4.2.3: Stock in and out by year for high cost items.

Items	Stock In/Out by Year						Remaining Spare
	2013		2014		2015		
	In	Out	In	Out	In	Out	
Complete Set Motorised Parallel Slide Gate Valve (Without Actuator)(3")	14	12	14	12	12	10	6
Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	8	6	10	6	8	6	8
Complete Set Motorised Globe Valve (Without Actuator)(3")(HAC60))	8	6	6	7	8	5	4
Pressure Seal Bonnet : A105/A350LF2 + STELLITE	14	12	10	9	10	10	3
Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	8	6	4	6	8	6	2
Complete Set Motorised Globe Valve (Without Actuator)- HAC 40	14	14	8	8	10	6	4
Complete Set Motorised Globe Valve (Without Actuator)(HAC60)	8	8	4	6	8	5	3
Complete Set Motorised Globe Valve(HAJ02)	8	8	4	5	6	5	1
Complete Set Motorised Globe Valve (Without Actuator) -flange	8	8	4	6	6	5	1
complete set motorised globe valve (without actuator) A 105	8	4	2	4	6	4	4

Table 4.2.4: Optimized spares for high cost items.

Items	Failure Approximation (mean)	Remaining Spare In Stock	Stock To Be Purchased by Company	Proposed Stock To Be Purchased
Complete Set Motorised Parallel Slide Gate Valve (Without Actuator)(3")	12	6	12	6
Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	7	8	6	0
Complete Set Motorised Globe Valve (Without Actuator)(3")(HAC60))	7	4	6	3
Pressure Seal Bonnet : A105/A350LF2 + STELLITE	11	3	12	8
Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	6	2	6	4
Complete Set Motorised Globe Valve (Without Actuator)- HAC 40	11	4	12	7
Complete Set Motorised Globe Valve (Without Actuator)(HAC60)	6	3	6	3
Complete Set Motorised Globe Valve(HAJ02)	6	1	6	5
Complete Set Motorised Globe Valve (Without Actuator) -flange	6	1	6	5
complete set motorised globe valve (without actuator) A 105	4	4	6	0

4.3 Movement Analysis

The spares must undergo movement analysis to identify their pattern of demand and how long it can be kept before becoming obsolete item. The spares can be divided into three movement class which are slow moving items, fast moving items and non-moving or obsolete items. In this section, only two types of movement will be covered which are slow moving items and fast moving items where the obsolete items will be covered in **Section 4.3.1**.

Table 4.3.1: Spares and their failures in the past three years.

Items	Failure by Year		
	2013	2014	2015
Complete Set Motorised Parallel Slide Gate Valve (Without Actuator)(3")	14	12	10
Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	10	6	6
Complete Set Motorised Globe Valve (Without Actuator) (3") (HAC60)	8	7	5
Pressure Seal Bonnet : A350 LF2 + Stellite	24	17	17
Pressure Seal Bonnet : A105/A350LF2 + STELLITE	15	9	10
Complete Set Motorised Globe Valve (Without Actuator)- HAC 40	14	8	6
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	28	16	18
Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	6	6	6
Complete Set Motorised Globe Valve (Without Actuator)(HAC60)	8	6	5
Complete Set Motorised Globe Valve(HAJ02)	8	5	5
Dics: A 350 LF2 + STELLITE	10	9	10
Complete Set Motorised Globe Valve (Without Actuator) -flange	8	6	5
Complete Set Motorised Globe Valve (Without Actuator)(1")(HAH92)	15	10	10
complete set motorised globe valve (without actuator) A 105	4	4	4
Dics: A105/A350LF2 + STELLITE	5	6	5
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	10	12	10
Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	14	9	9
Dics: A 350 LF2 + STELLITE for 3"	5	5	4
Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	14	9	10

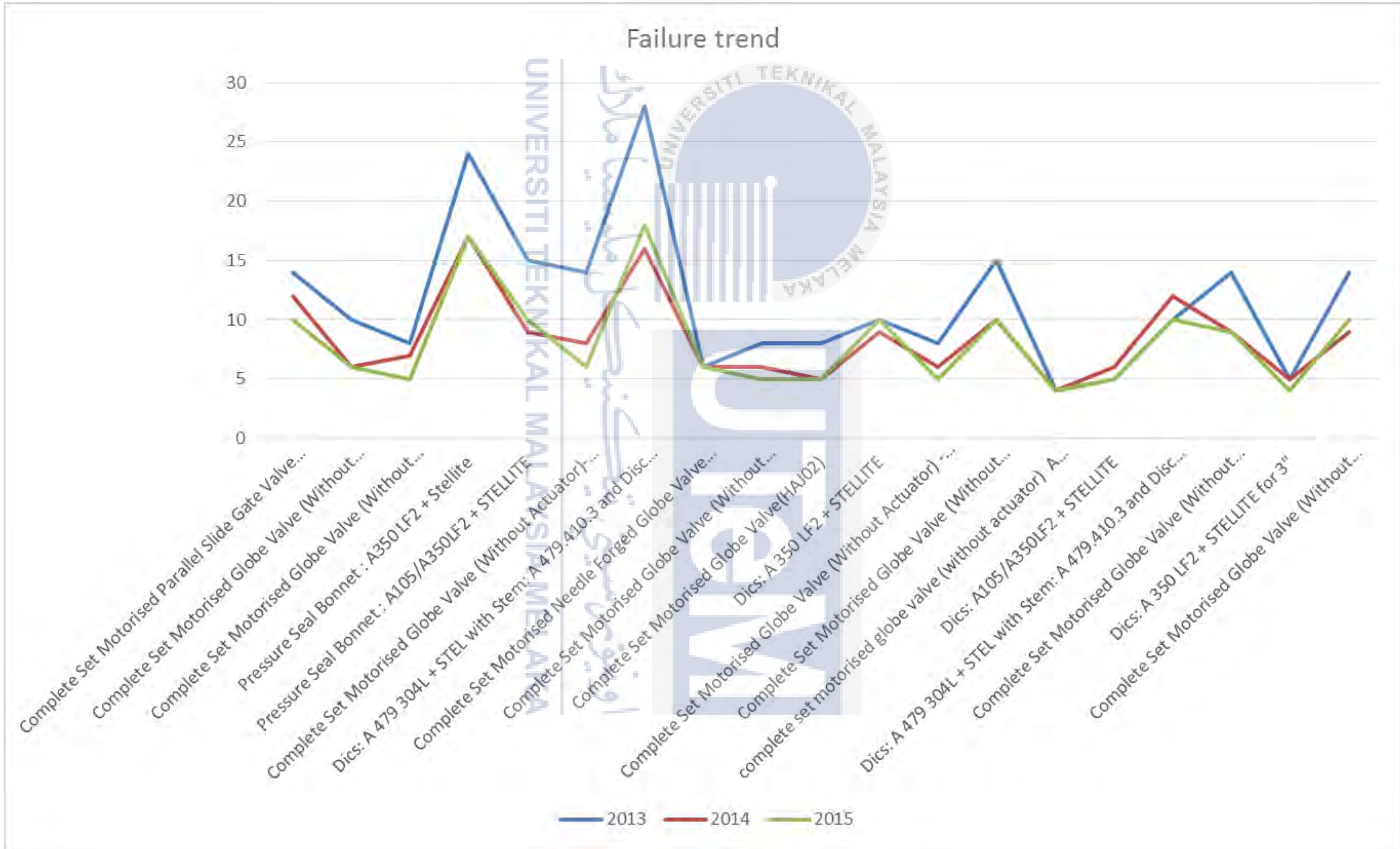

Figure 4.3: Failure trend chart based on past three years

Based on the failure frequency, the spares were divided into two section which are slow moving items and fast moving items. For slow moving items, the MTTF is higher than fast moving items. This is because the failure rate frequency is lower and it takes approximately two month for one failure. As a results the quantity for slow moving items is less than the quantity of fast moving items. From the frequency of failure, the items were divided as shown in the **Table 4.3.2**. Besides that, the high cost items had been eliminated in this step as the item have been optimized in the previous section.

Table 4.3.2: Fast moving items and slow moving items

Fast Moving Items	Slow Moving Items
Pressure Seal Bonnet : A350 LF2 + Stellite	Dics: A105/A350LF2 + STELLITE
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	Dics: A 350 LF2 + STELLITE for 3"
Dics: A 350 LF2 + STELLITE	
Complete Set Motorised Globe Valve (Without Actuator)(1")(HAH92)	
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	
Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	
Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	

By following the step in the methodology, the fast moving items need to be optimised first as the rate of failure is higher than slow moving items. Therefore, the failure trend analysis and the spares left in the inventory for the fast moving items had been analysed in order to complete the result.

Table 4.3.3: Failure forecasting for fast moving items

Items	Failure by Year			Failure Approximation (mean)
	2013	2014	2015	
	Out	Out	Out	
Pressure Seal Bonnet : A350 LF2 + Stellite	24	17	17	20
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	28	16	18	21
Dics: A 350 LF2 + STELLITE	10	9	10	10
Complete Set Motorised	15	10	10	12

Globe Valve (Without Actuator)(1")(HAH92)				
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	10	12	10	11
Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	14	9	9	11
Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	14	9	10	11

By analysing the stock in and out of the spare, the remaining items from the past years can be calculated and the total spares issued by the company for fast moving items can be minimized. Besides that, due to fast moving item having more frequent failure than low moving items, the lead time is very important and need to be consider. Therefore, after considering the lead time that need to be taken, the optimized number must be added by 1 item each as the precaution for the case. After the analysis have been done, the final optimised spares for fast moving item was tabulated in **Table 4.3.5**.

Table 4.3.4 Stock in and out by year for fast moving items.

Items	Stock In/Out by Year						Remaining Spare
	2013		2014		2015		
	In	Out	In	Out	In	Out	
Pressure Seal Bonnet : A350 LF2 + Stellite	26	24	18	17	16	17	2
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	26	28	18	16	18	18	2
Dics: A 350 LF2 + STELLITE	14	10	8	9	10	10	3
Complete Set Motorised Globe Valve (Without Actuator)(1")(HAH92)	14	15	8	10	10	10	0
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	14	10	8	12	12	10	2
Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	14	14	8	9	10	9	1
Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	14	14	8	9	8	10	0

Table 4.3.5: Optimized spares for fast moving items.

Items	Failure Approximation (mean) + 1 (lead time consideration)	Remaining Spare In Stock	Stock To Be Purchased by Company	Proposed Stock To Be Purchased
Pressure Seal Bonnet : A350 LF2 + Stellite	21	2	24	19
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	22	2	24	20
Dics: A 350 LF2 + STELLITE	11	3	12	8
Complete Set Motorised Globe Valve (Without Actuator)(1")(HAH92)	13	0	12	13
Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	12	2	12	10
Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	12	1	12	11
Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	12	0	12	12

4.4 Obsolete Items

Obsolete item is the spare that expired or cannot be used anymore because of functional failure, over audit period or having reached the end of product life cycle. In the plant, the obsolete items that must be prioritized is the item that over the audit period. This is because all of the item in the inventory must be checked monthly in order to avoid any functional failure but the possibilities of the inventory department to overlook the item causing an over the audit period.

This problem can lead to the waste of inventory money and space. At the power plant, the audit limit is three years. Therefore, any equipment and data for the past three years must be saved in order to complete the audit. If the items in the inventory was more than three years it cannot be used as the items need to be transferred to the scarp inventory. Consequently, from the company's audit policy, researcher found that it can be sold and the company can gain some money as the items are still functioning well and have not used yet. In addition, the items can be easily sold as it is highly on demand and the suppliers also have the interest to buy it. However, the policy used by the company need to be recomposed because most of the items still can be used and it will be wasted if the company do not used it. A list of obsolete items and their expected selling price have been tabulated as shown in **Table 4.4**.

Table 4.4: Obsolete items and expected price

Obsolete Items (not move in 3 years)	Quantity	Expected Price per item (RM)	Total (RM)
Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	2	95,000.00	190,000.00
Complete Set Motorised Globe Valve (Without Actuator)- HAC 40	1	25,000.00	25,000.00
Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	1	5,000.00	5,000.00
		Total	**220,000.00**

4.5 Common Spares and Infrequent Spares

Common spares is the spares that company maintain their level because the failure usually occur at a certain frequency where infrequent spare is the spare that show a variability frequency of failure and usually the quantity is lower than common spare. For the next step of spares optimization, researcher need to divide the slow moving item into two subdivision which are common spares and infrequent spares. From this division, researcher used the same methods which are failure trend analysis and remaining spares but it is different with fast moving analysis as the lead time is not a concern to the researcher. This is due to the value of MTTF higher than the fast moving items and the company have time to do the new order if the quantity reach lowered than the required number of item. However in this case, the spares existed are only common spares. Therefore only common spare class will be covered in this section.

Table 4.5.1: Common and infrequent spares for slow moving item.

Common Spares
Dics: A105/A350LF2 + STELLITE
Dics: A 350 LF2 + STELLITE for 3"

For the slow moving items, the company needs to optimize the number as the lead time is not too important because it has lower failure frequency than the other especially for the common spares. This is because the common spares usually have the same number of issue and if the number can be optimized, it will affect the sequence of order for the next batch. Therefore, it is compulsory for researcher to optimize the number of slow moving item for the company. Based on **Table 4.5.2**, the trend analysis can be analysed to form a optimize number of spares.

Table 4.5.2: Failure forecasting for slow moving items

Items	**Failure by Year**			**Failure Approximation (mean)**
	2013	**2014**	**2015**	
	Out	**Out**	**Out**	
Dics: A105/A350LF2 + STELLITE	5	6	5	5
Dics: A 350 LF2 + STELLITE for 3"	5	5	4	5

From the table above, a new list of common spares can be used for the next order and the value can decreased the cost for spares issue as the quantity of the spare had been optimized. For the spare issue, compared issues was made on the remaining spares in the inventory and optimized list to ensure the cost for spares issue can be decreased. **Table 4.5.3** show the remaining spares in the inventory while **Table 4.5.4** show finalised spares that needs to be issued by the company.

Table 4.5.3 Stock in and out by year for slow moving items.

Items	Stock In/Out by Year						Remaining Spare
	2013		2014		2015		
	In	Out	In	Out	In	Out	
Dics: A105/A350LF2 + STELLITE	8	5	4	6	6	5	2
Dics: A 350 LF2 + STELLITE for 3"	8	5	4	5	6	4	4

Table 4.5.4: Optimized spares for low cost item.

Items	Failure Approximation	Remaining Spare	Current spare issued	Optimized spare
Dics: A105/A350LF2 + STELLITE	5	2	6	3
Dics: A 350 LF2 + STELLITE for 3"	5	4	6	1

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Recommended Spare List

The main purpose of this research is to optimize the spare proposed by the company. Therefore, after conduct various analysis, a list of optimized spare had been prepared and tabulated as shown in **Table 5.1.1**.

Table 5.1.1: Optimized spares proposed by the company.

No.	Items	Spares issue before optimization	Spares issue after optimization	Changes (-) = deducted (+) = added
1	Complete Set Motorised Parallel Slide Gate Valve (Without Actuator)(3")	12	6	-6
2	Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	6	0	-6
3	Complete Set Motorised Globe Valve (Without Actuator)(3")(HAC60))	6	3	-3
4	Pressure Seal Bonnet : A350 LF2 + Stellite	24	19	-5
5	Pressure Seal Bonnet : A105/A350LF2 + STELLITE	12	8	-4
6	Complete Set Motorised Globe Valve (Without Actuator)- HAC 40	12	7	-5
7	Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	24	20	-4
8	Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	6	4	-2
9	Complete Set Motorised Globe Valve (Without Actuator)(HAC60)	6	3	-3
10	Complete Set Motorised Globe Valve(HAJ02)	6	5	-1
11	Dics: A 350 LF2 +	12	8	-4

	STELLITE			
12	Complete Set Motorised Globe Valve (Without Actuator) -flange	6	5	-1
13	Complete Set Motorised Globe Valve (Without Actuator)(1")(HAH92)	12	13	+1
14	complete set motorised globe valve (without actuator) A 105	6	0	-6
15	Dics: A105/A350LF2 + STELLITE	6	3	-3
16	Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	12	10	-2
17	Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	12	12	0
18	Dics: A 350 LF2 + STELLITE for 3"	6	1	5
19	Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	12	12	0

Based on the **Table 5.1.1**, sixteen of the spares have decreased in their quantity where two of them remain unchanged and one of the item increase by one unit. In addition, the changes in their number indirectly will affect the cost of spares proposed by the company. **Table 5.1.2** will show the change in value of the spare after optimization of the spares had been done.

Table 5.1.2: Cost changes for new proposed list.

No.	Items	Spares issue before optimization	Spares issue after optimization	Changes in Cost (RM) (-) = deducted (+) = added
1	Complete Set Motorised Parallel Slide Gate Valve (Without Actuator)(3")	12	6	-484,344.00
2	Complete Set Motorised Globe Valve (Without Actuator)(4")(HAC69)	6	0	-490,409.00
3	Complete Set Motorised Globe Valve (Without Actuator)(3")(HAC60))	6	3	-240,630.90
4	Pressure Seal Bonnet :	24	19	-81,574.00

	A350 LF2 + Stellite			
5	Pressure Seal Bonnet : A105/A350LF2 + STELLITE	12	8	-126,495.20
6	Complete Set Motorised Globe Valve (Without Actuator)- HAC 40	12	7	-142,765.00
7	Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L-HAC	24	20	-49,288.00
8	Complete Set Motorised Needle Forged Globe Valve (Without Actuator)	6	4	-66,339.00
9	Complete Set Motorised Globe Valve (Without Actuator)(HAC60)	6	3	-90,456.90
10	Complete Set Motorised Globe Valve(HAJ02)	6	5	-29,058.80
11	Dics: A 350 LF2 + STELLITE	12	8	-57,159.20
12	Complete Set Motorised Globe Valve (Without Actuator) -flange	6	5	-28,343.30
13	Complete Set Motorised Globe Valve (Without Actuator)(1")(HAH92)	12	13	+13,980.00
14	complete set motorised globe valve (without actuator) A 105	6	0	-153,778.80
15	Dics: A105/A350LF2 + STELLITE	6	3	-74,904.90
16	Dics: A 479 304L + STEL with Stem: A 479.410.3 and Disc Nut : A 479 304L	12	10	-24,462.00
17	Complete Set Motorised Globe Valve (Without Actuator)(1 1/2")(HAH83)	12	12	0.00
18	Dics: A 350 LF2 + STELLITE for 3"	6	1	-96,626.50
19	Complete Set Motorised Globe Valve (Without Actuator)(HAH24)	12	12	0.00
TOTAL				**-2,222,655.50**

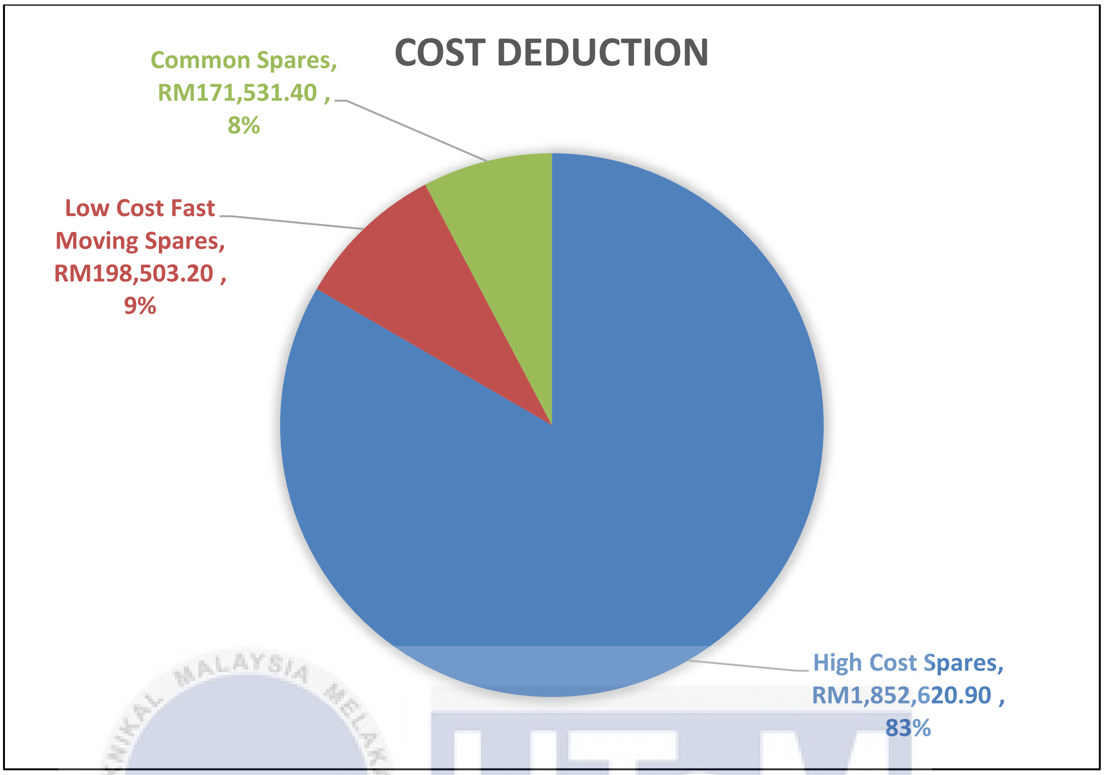

Figure 5.1: Cost deducted according to methodology steps.

Based on the **Figure 5.1**, the pie chart shown the cost deducted by each methods for optimizing the spare. The highest percentage is 83 percent which is represent by the high cost spare. This is due to the price of the items itself which are very expensive and need to be import from the other country. By optimizing the high cost spare, the cost was reduced by RM 1,852,620.90 from the total cost and that is a lot of money.

5.2 Direct and Indirect Effect by Optimizing the Spares

Based on the result and analysis in **Chapter 4** and **Section 5.1**, there are some value which will affect the other measurement directly and indirectly. Firstly, the total cost issue from the company and total cost issue by researcher.

Total cost issue by the company = RM 6,643,649.50

Total cost issue by researcher = RM 4,420,994.00

Percentage of cost deduction $= \frac{\text{Cost Deducted}}{\text{Total Initial Cost}} \text{ X } 100\%$

$= \frac{2,222,655.50}{6,643,649.50} \text{ X } 100\%$

= 33.46%

From the calculation, researcher decreased the cost by 33 percent of the initial total cost issue by the company. Although the percentage is not reach 50 percent, but in form of the value it quite a lot. Besides that, there are some measurement that indirectly will be effected by the optimization such as inventory turnover and stock out index.

Table 5.2: Indirect measurement that effected by spares optimization.

Spares Consumed By Company	Proposed Spares By Researcher
Inventory turnover $= \frac{\text{Cost of issues}}{\text{Inventory value}}$ $= \frac{\text{RM 6,643,649.50}}{\text{RM 275 million}}$ =**0.0242 @ 2.42%**	Inventory turnover $= \frac{\text{Cost of issues}}{\text{Inventory value}}$ $= \frac{\text{RM 4,420,994.00}}{\text{RM 275 million}}$ =**0.0161 @1.61%**
Stock issue index $= \frac{\text{Stock issue this year}}{\text{Stock issue last year}}$ $= \frac{\text{RM 6,643,649.50}}{\text{RM 6,435,843.70}}$ = 1.0323	Stock issue index $= \frac{\text{Stock issue this year}}{\text{Stock issue last year}}$ $= \frac{\text{RM 4,420,994.00}}{\text{RM 6,435,843.70}}$ = 0.6869

5.3 Conclusion

In the nutshell, to optimize the spares issue by the company, researcher used variable type of analysis such as Pareto Analysis, Failure Trend Analysis, Movement analysis and Stock in Stock Out Analysis were used. All of this analyse need to be done to ensure the optimization of the spare can be successfully completed. Based on the result and analysis, researcher decreased the cost for spares issue by 33.46 percent or inform of value the cost was deducted by RM 2,222,655.50 and it is lot of company's money. Therefore, the first objective in this project had been successfully achieved.

Besides that, the inventory turnover also decreased by 1.61 percent compared to company issued which is 2.42 percent and this decreasing of inventory turnover is a good indicator for the company. In addition, the stock issue index also showed some decreasing in form of their percentage which is 68.23 percent compared to 103.23 percent that issued by the company. When the percentage exceed 100 percent, it showed that expenses of the company is increasing and any increasing may lead to company loss. Because of the increasing is only 3.23 percent, the company overlooked on the spares issues and take it lightly as the profit of the company is very high compared to the spares issued.

By optimizing the spares, the availability of the plant increased as the spares at optimized quantity based on the failure analysis and this will indirectly will increased the reliability of the plant. Besides that, by increasing the availability of a machine in the plant, the downtime of the machine will decrease and it correspondingly will increase the reliability of the plant. Therefore the second objective which is to increase the reliability and availability of the machine in the plant is also achieved

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APPENDICES

Measurement	Value/year
Downtime • Schedule • Unscheduled	 • 816h • 1221.6h
No of work orders	13676
Total working hours per person	1920h
Inventory value	RM 275 million
Stock issue (Valve): • Stock issue this year • Stock issue last year	 • RM 6,643,649.50 • RM 6,435,843.70
Production losses • last month • previous month	 • 22h • 10h
Wrench time	5030h
No of staff maintenance	30
Lost production time cost/hour	RM 100k
Fuel consumption • Coal • Light fuel oil (diesel)	 • 9.46 million ton • 3.1 million litre

LAMPIRAN A

No Kontrak : TNBJ/KON/[redacted]

Keterangan :
TAWARAN "SUPPLY OF COMPLETE SET OF BOILER DRAIN VALVE (WITHOUT ACTUATOR) & SPARE PARTS" UNTUK BAHAGIAN SENGGARAAN DANDANG DI SJ SULTAN AZLAN SHAH, MANJUNG.

Tempoh Kontrak : Satu (1) TAHUN Dua (2) BULAN - [redacted].

Tawaran melalui tender bernombor rujukan TNBJ/SJM [redacted] **adalah menjadi sebahagian dari syarat-syarat kontrak.**

JADUAL HARGA

No.	Items / Details of specification	Estimated Price			
		Material Number	Quantity	Unit Price (RM)	Total (RM)
1	**Items**: Complete Set Motorised Globe Valve (Without actuator) **Manufacturer**: SAPAG (2 1/2") **KKS Code:** HAC 60 AA 422 M	11093620	6 sets	30,152.30	**180,913.80**
	Spare Part: 1) Dics: A 479 304L + STELL 2) Stem: A 479.410.3 3) Graphite Gasket Material : 9593-6 Please Refer ***Drawing No.1*** for Details	11093775 11093781 11093087	6 nos 6 nos 12 nos	11,475.00 **-Included-** 1,255.80	**68,850.00** **15,069.60**
4	**Items**: Complete Set Motorised Parallel Slide Gate Valve (Without Actuator) **Manufacturer**: SAPAG (3") **KKS Code:** HAH 81 AA 403 M	11105097	6 sets	80,724.00	**484,344.00**
	Spare Part: 1) Dics: A 350 LF2 + STELLITE 2) Stem: AISI 431 3) Pressure Seal : Graphite 4) Pressure Seal Bonnet : A350 LF2 + Stellite Please Refer ***Drawing No.3*** for Details	11093729 11093745 11093309 11105100	6 nos 6 nos 12 nos 12 nos	14,289.80 8,428.80 3,238.10 16,314.80	**85,738.80** **50,572.80** **38,857.20** **195,777.60**

5	**Items**: Complete Set Motorised Parallel Slide Gate Valve (Without Actuator) **Manufacturer**: SAPAG (3") **KKS Code:** HAH 82 AA 403 M	11105097	6 sets	80,724.00	**484,344.00**
	Spare Part: 1) Dics: A 350 LF2 + STELLITE 2) Stem: AISI 431 3) Pressure Seal : Graphite 4) Pressure Seal Bonnet : A350 LF2 + Stellite	 11093729 11093745 11093309 11105100	 6 nos 6 nos 12 nos 12 nos	 14,289.80 8,428.80 3,238.10 16,314.80	 **85,738.80** **50,572.80** **38,857.20** **195,777.60**
	Please Refer ***Drawing No.3*** for Details				
12	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: SAPAG (2 1/2") **KKS Code:** HAJ 01 AA 402 M	11135524	6 sets	25,629.80	**153,778.80**
	Spare Part: 1) Dics: Steel A 105 / Stellite 2) Stem: Stainless Steel A 564 Type 632 3) Body/Bonnet Gasket: Graphite	11093768 11093783 11093080	6 nos 6 nos 12 nos	10,476.00 **-Included-** 1,228.50	**62,856.00** **14,742.00**
	Please Refer ***Drawing No.7*** for Details				
13	**Items**: Complete Set Motorised Globe Valve **Manufacturer**: SAPAG (2 1/2") **KKS Code:** HAJ 02 AA 402 M	11135525	6 sets	29,058.80	**174,352.80**
	Spare Part: 1) Dics: Steel A 105 / Stellite 2) Stem: Stainless Steel A 564 Type 632 3) Body/Bonnet Gasket: Graphite	11093768 11093783 11093080	6 nos 6 nos 12 nos	10,476.00 **-included-** 1,228.50	**62,856.00** **14,742.00**
	Please Refer ***Drawing No.7*** for Details				
16	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: SAPAG (2.5") **KKS Code:** HAD 01 AA 455 H	TBA	6 sets 12 nos	28,343.30 **-included-**	**170,059.80**
	Spare Part: 1) Dics: A 479 304L + STEL. 2) Stem: A 479.410.3 3) Disc Nut : A 479 304L 4) Lock Nut : A 540 B 22	 11093772 11093792 11093157 11093790	12 nos 12 nos 12 nos 12 nos 12 nos	**-included-** 12,231.00 **-included-** **-included-** 1,255.80	 **146,772.00** **15,069.60**

	5) Thrust Disc : A 314 GR 440C 6) Graphite gasket : 9593-6 Please Refer ***Drawing No.8*** for Details	11093793 11093791			
17	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: SAPAG (3") **KKS Code:** HAC 60 AA 413 H	11093622 11104988	6 sets	80,210.30	**481,261.80**
	Spare Part: 1) Dics: A 350 LF2 + STELLITE 2) Stem: AISI 431 3) Gasket : Graphite Please Refer ***Drawing No.9*** for Details	 11093773 11093779 11093085	 6 nos 6 nos 12 nos	 19,325.30 9,439.40 5,940.00	 **115,951.80** **56,636.40** **71,280.00**
19	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: SAPAG (4") **KKS Code:** HAC 69 AA 402 H	11135527	6 sets	98,401.50	**590,409.00**
	Spare Part: 1) Dics: A105/A350LF2 + STELLITE 2) Stem: AISI 431 3) Pressure Seal : Graphite 4) Pressure Seal Bonnet : A105/A350LF2 + STELLITE Please Refer ***Drawing No.11*** for Details	 11093774 11093780 11093086 11104987	 6 nos 6 nos 12 nos 12 nos	 24,968.30 11,708.10 6,768.90 31,623.80	 **149,809.80** **70,248.60** **81,226.80** **379,485.60**
20	**Items**: Complete Set Motorised Needle Forged Globe Valve (Without Actuator) **Manufacturer**: SAPAG (2 1/2") **KKS Code:** HAD 01 AA 452 M	11107203	6 sets	33,169.50	**199,017.00**
	Spare Part: 1) Dics: A 479 304L + STELLITE 2) Stem: AISI 431 3) Disc Nut : A 479 304L 4) Lock Nut : A 540 B 22 5) Thrust : A 314 GR 440 C 6) Gasket : Graphite Please Refer ***Drawing No.12*** for Details	 11093776 11093786 11093161 11093798 11093799 11093088	 6 nos 6 nos 6 nos 6 nos 6 nos 12 nos	 **-included-** **-included-** 12,856.30 **-included-** **-included-** 1,255.80	 **77,137.80** **15,069.60**
	JUMLAH KESELURUHAN (RM)			5,078,177.40	

Attachment :

Contract No: TNBJ/KON/[redacted] - PO [redacted]

Description:
TO SUPPLY OF COMPLETE SET OF BOILER DRAIN VALVE (WITHOUT ACTUATOR) & SPARE PARTS FOR BOILER MAINTENANCE SECTION, SJ SULTAN AZLAN SHAH MANJUNG.

Contract Period: [redacted]

Refer quotation submission TNBJ/SJM [redacted] General Condition Of Contract (Appendix 1) is include in this Contract.

SCHEDULES PRICE

No.	Items / Details of specification	Estimated Price			
		Material Number	Quantity	Unit Price (RM)	Total (RM)
2	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (1 1/2") **KKS Code:** HAH 83 AA 403 M	11103794	6 sets	10,900.00	**65,400.00**
	Spare Part: 1) Dics: AISI420+St 2) Stem: ASTM A182 F6 3) Pressure Seal: AISI 316 4) Pressure Seal Cover: AISI 420 Please Refer ***Drawing No.2*** for Details	11103795 11103796 11103800 11103798	6 nos 6 nos 12 nos 12 nos	1,560.00 1,570.00 1,480.00 1,470.00	**9,360.00** **9,420.00** **17,760.00** **17,640.00**
3	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (1 1/2") **KKS Code:** HAH 84 AA 403 M	11103794	6 sets	10,895.00	**65,370.00**
	Spare Part: 1) Dics: AISI420+St 2) Stem: ASTM A182 F6 3) Pressure Seal: AISI 316 4) Pressure Seal Cover: AISI 420 Please Refer ***Drawing No.2*** for Details	11103795 11103796 11103800 11103798	6 nos 6 nos 12 nos 12 nos	1,550.00 1,560.00 1,480.00 1,470.00	**9,300.00** **9,360.00** **17,760.00** **17,640.00**
6	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (1")	11103784	6 sets	13,980.00	**83,880.00**

	KKS Code: HAH 92 AA 402 M **Spare Part**: 1) Dics: AISI316+St 2) Stem: AISI316 3) Pressure Seal: AISI 316 4) Pressure Seal Cover: AISI 420 Please Refer ***Drawing No.4*** for Details	11103785 11103786 11103790 11103788	6 nos 6 nos 12 nos 12 nos	1,590.00 1,550.00 699.00 1,700.00	**9,540.00** **9,300.00** **8,388.00** **20,400.00**
7	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (1") **KKS Code:** HAH 93 AA 402 M **Spare Part**: 1) Dics: AISI316+St 2) Stem: AISI316 3) Pressure Seal: AISI 420 4) Pressure Seal Cover: AISI 420 Please Refer ***Drawing No.4*** for Details	11103784 11103785 11103786 11103790 11103788	6 sets 6 nos 6 nos 12 nos 12 nos	13,960.00 1,590.00 1,550.00 699.00 1,700.00	**83,760.00** **9,540.00** **9,300.00** **8,388.00** **20,400.00**
8	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (1") **KKS Code:** HAJ 03 AA 402 M **Spare Part**: 1) Dics: AISI420/STELLITE 2) Stem: AISI416 3) Bonnet Gasket : AISI316 Please Refer ***Drawing No.5*** for Details	11103811 11103821 11103813 11103817	6 sets 6 nos 6 nos 12 nos	3,200.00 860.00 860.00 540.00	**19,200.00** **5,160.00** **5,160.00** **6,480.00**
9	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (1") **KKS Code:** HAJ 04 AA 402 M **Spare Part**: 1) Dics: AISI420/STELLITE 2) Stem: AISI416 3) Bonnet Gasket : AISI316 Please Refer ***Drawing No.5*** for Details	11103811 11103821 11103813 11103817	6 sets 6 nos 6 nos 12 nos	3,150.00 850.00 850.00 530.00	**18,900.00** **5,100.00** **5,100.00** **6,360.00**
10	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (2")	 11103860	6 sets 6 nos	8,780.00 2,160.00	**52,680.00** **12,960.00**

	KKS Code: HAH 22 AA 402 M **Spare Part**: 1) Dics: AISI420/ Stellite 2) Stem: ASTM A182 F6 3) Pressure Seal: AISI 316 4) Pressure Seal Bonnet: ASTM A105N Please Refer ***__Drawing No.6__*** for Details	 11103861 11103865 11103866 11103870	6 nos 12 nos 12 nos	2,160.00 1,770.00 670.00	**12,960.00** **21,240.00** **8,040.00**
11	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (2") **KKS Code:** HAH 24 AA 402 M **Spare Part**: 1) Dics: AISI420/ Stellite 2) Stem: ASTM A182 F6 3) Pressure Seal: AISI 316 4) Pressure Seal Bonnet: ASTM A105N Please Refer ***__Drawing No.6__*** for Details	11103860 11103861 11103865 11103866 11103870	6 sets 6 nos 6 nos 12 nos 12 nos	8,790.00 2,165.00 2,165.00 1,760.00 660.00	**52,740.00** **12,990.00** **12,990.00** **21,120.00** **7,920.00**
18	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: U.P.V (2") **KKS Code:** HAH 20 AA 402 H **Spare Part**: 1) Dics: AISI420+St 2) Stem: ASTM A182 F6 3) Pressure Seal : AISI 316 4) Pressure Seal Cover : ASTM A182 F6 Please Refer ***__Drawing No.10__*** for Details	TBA 11103690 11103691 11111058 11103692	6 sets 6 nos 6 nos 12 nos 12 nos	8,850.00 2,160.00 2,160.00 1,740.00 650.00	**53,100.00** **12,960.00** **12,960.00** **20,880.00** **7,800.00**
				JUMLAH KESELURUHAN (RM)	**896,706.00**

Attachment :

Contract No: TNBJ/KON/16/[redacted] [redacted]

Description:
TO SUPPLY OF COMPLETE SET OF BOILER DRAIN VALVE (WITHOUT ACTUATOR) & SPARE PARTS FOR BOILER MAINTENANCE SECTION, SJ SULTAN AZLAN SHAH MANJUNG.

Contract Period: One (1) years - [redacted] [redacted]

Refer quotation submission TNBJ/SJM [redacted] [redacted] General Condition Of Contract (Appendix 1) is include in this Contract.

SCHEDULES PRICE

No.	Items / Details of specification	Estimated Price			
		Material Number	Quantity	Unit Price (RM)	Total (RM)
14	**Items**: Complete Set Motorised Globe Valve (Without actuator) **Manufacturer**: SAPAG (2 1/2") **KKS Code:** HAC 40 AA 402 H	TBA	6 sets	28,553.00	**171,318.00**
	Spare Part:				
	1) Dics: A 479 304L + STEL.	11093772	12 nos	-included-	
	2) Stem: A 479.410.3	11093792	12 nos	-included-	
	3) Disc Nut : A 479 304L	11093157	12 nos	12,322.00	**147,864.00**
	4) Lock Nut : A 540 B 22	11093790	12 nos	-included-	
	5) Thrust Disc : A 314 GR 440C	11093793	12 nos	-included-	
	6) Graphite gasket : 9593-6	11093791	12 nos	1,238.00	**14,856.00**
	Please Refer ***Drawing No.8*** for Details				
15	**Items**: Complete Set Motorised Globe Valve (Without Actuator) **Manufacturer**: SAPAG (2 1/2") **KKS Code:** HAD 01 AA 453 H	TBA	6 sets	28,553.00	**171,318.00**
	Spare Part:				
	1) Dics: A 479 304L + STEL.	11093772	12 nos	-included-	
	2) Stem: A 479.410.3	11093792	12 nos	-included-	
	3) Disc Nut : A 479 304L	11093157	12 nos	12,322.00	**147,864.00**
	4) Lock Nut : A 540 B 22	11093790	12 nos	-included-	
	5) Thrust Disc : A 314 GR 440C	11093793	12 nos	-included-	
	6) Graphite gasket : 9593-6	11093791	12 nos	1,238.00	**14,856.00**
	Please Refer ***Drawing No.8*** for Details				
			JUMLAH KESELURUHAN (RM)	**668,076.00**	