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IMPLEMENTATION OF TOTAL PRODUCTIVE MAINTENANCE CONCEPT IN A FERTILIZER PROCESS PLANT

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ABSTRACT

Machine breakdown due to unplanned maintenance (sudden failure) will increase the repair cost and machine downtime (production lost). This has brought the function of maintenance to be an important activity in the manufacturing industry in order for daily operation to become stable. The introduction of several philosophies such as Corrective Maintenance (CM), Preventive Maintenance (PM) or Total Productive Maintenance (TPM) have allowed extra solutions to a process planning problem faced by company in comparison to the conventional fire-fighting syndrome. This main purpose of this study was to focus on developing a framework of maintenance strategy as guidelines for Mechanical Section in Engineering Department for Malaysian NPK Fertilizer Sdn. Bhd. (MNFSB) located in Gurun Industrial Estate, Kedah. From an extensive review of literature for Total Productive Maintenance (TPM), twelve disciplines beginning with basic to advanced elements were identified for effective Maintenance Management Systems. To demonstrate the validity of this study, it was tested by implementing it on actual equipment, namely as Bucket Conveyor, EL102 as a case study.

Keywords: *Total productive maintenance (TPM), maintenance management system framework, bucket conveyor EL102*

1.0 INTRODUCTION

The field of business operations and management is becoming more competitive in recent decade, which makes industries interested in developing modern management system in order to stay competitive in managing their business operations. Such competitive advantage can help companies to become more successful. In term of the business operations, companies are re-examining their maintenance department function as an effective management system in order to identify opportunities for improvements. Traditionally, maintenance role always relate to fire-fighting and stop-the-bleeding scenario. However, in recent years, many companies start to embark into new maintenance management systems that utilize latest technology. This trend has been steadily growing in many industries, such as in the airline industry, manufacturing industry and heavy industries likes cement plant, quarry plant, fertilizer plant and oil and gas industry. In this study, the authors are proposing the use of twelve disciplines as a maintenance management system framework as a guideline for Mechanical Section in Engineering Department at Malaysian NPK Fertlizer Sdn. Bhd. (MNFSB) which was chosen as the case study in this research. In order to explain the detail on how the

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proposed system works, the twelve disciplines was embedded into actual equipment namely as Bucket Conveyor EL102. The production processes were observed, and formal discussions made with related company personnel. This was followed by data collection and to look at the company's historical data to identify the major machine downtime problems. Related analysis was employed in carrying out a detailed study in order to identify the problems. The problems which are of company concern are high downtime recorded for Bucket Conveyor El102 since plant commissioning although the equipment is not the most critical downtime contribution found in Pareto analysis. Then, the development process of the framework will be discussed in details to overcome these problems and to provide a better maintenance management system. Numerous benefits can be associated with a successful implementation of TPM such as reduced downtime, improved reliability of processes, improved spare parts management, reduced cost of production losses and improved corporate competitive advantage. Finally, we conducted before and after comparison, to evaluate the system performance in terms of its downtime reduction and production cost of losses justification.

2.0 LITERATURE REVIEW

2.1 Overview of TPM

Total Productive Maintenance (TPM) is a methodology to form a corporate culture focus on maximizing the efficiency of overall production system through cross-functional section (Venkataraman, 2007). According to Angeles (2009), TPM can be described as a plant improvement methodology which enables continuous and rapid improvement of the manufacturing process through the use of employee involvement, employee empowerment and closed-loop measurement of results. It is a production driven improvement methodology that is designed to optimize equipment's reliability and ensure efficient management of plant assets. TPM also aims on building up a corporate culture that thoroughly pursues production systems efficiency improvement and Overall Equipment Efficiency (OEE). From both definition, it can be seen that they both describes a synergistic relationship among all organizational functions, but particularly between production and maintenance, for continuous improvement of product quality, operational efficiency, capacity assurance, safety and enhancement of the people who work within the company. It emphasizes maximizing Overall Equipment Effectiveness (OEE) through employee involvement. TPM activities involved all employees, starting from top management till ground floor operators. TPM program is marked to increase production while at the same time, increase employee morale and job satisfaction. In order to set up Total Productive Maintenance (TPM) framework, the understanding of it must be total. According to Nakajima (1989), the goal of Total Productive Maintenance (TPM) is continuously improve all operational conditions, within a production system by motivating the daily understanding of all employees.

2.2 Requirement of Establishing a Framework

Many authors have used the phrase "framework" without defining it properly. At this moment, there is no agreement on the true definition of the frameworks. Some authors define it as a set of principles or ideas used as a foundation for one decision, while others describe the frameworks through diagrams, flow charts, and graphical or pictorial representations (Yusof, 2000). Meanwhile, Struebing and Klaus (1997) understood that a framework should be define what the organization does, what it is trying to do, how it is going to do it and ensure that each step is done in the correct sequences. Then again, Popper (1994) as quoted by Yusof (2000) defines a framework as a set of basic fundamental principles, which can help to promote discussions and actions. According to Abdul Rahim and Nabi Baksh (2003), the framework ideally should consist of a conceptual and an operational structure. The conceptual structure is a crystallization of ideas in abstract form into a written form includes various interactive elements. The conceptual structure is actually a basic foundation of further works to be carried out. It should address the entire development process and act as a master plan for downstream activities. The operational structure is the derivative of the conceptual structure. At this level, the structure should be more detailed and practical in nature and self explanatory. The operational structure is normally divided into phases to make it more manageable. Procedures and process flowcharts can be derived from the operational structure. Table 1 summarized the requirements needs for establishing a framework.

Table 1: Framework requirement and specification

Framework requirement	Framework specification
Levels of framework	Framework divided into different levels to ease implementation
Generic and not prescriptive	Not too prescriptive like a cook book, should be able to be applied in many normal instances
Indicate clear direction design goals	Simple, straight forward, easy to understand, not expensive to implement, minimum time for implementation
Easy-to-follow approach	Smooth flow of the phases, reduce reverse flow, easy to follow
Aid in documentation process	Indicate important documentation requirement and document history
Key characteristics of design process	Indicate the activities of design process
Facilitate communication among functions and third parties	Involvement of marketing, purchasing, sales, after sales service, design, manufacturing, maintenance, suppliers, contractors, customers and service providers
Simple and practical plan for implementation	Simple and easy to understand without detailed explanation, self explanatory
Serve as a control mechanism	Structured plan with review and milestone, checklist to avoid omission
Integrate concurrent engineering tools	Integrate QFD, FMEA and DFA tools. Indicate when to use such tools
Include human interface	Human factors such as cross-functional team, teamworking, co-location, training

2.3 Maintenance Strategy

Maintenance strategy is a long-term plan, covering all aspects of maintenance management which sets the direction for maintenance management and contains firm action plans for achieving a desired future state for the maintenance function.

2.3.1 Basic Maintenance Strategy

To become world class in maintenance management, the discipline should start from the basics of maintenance. Basic discipline is the fundamental activities that should be performed on the equipment before going to any other stages. It is waste of money if company goes on enhancing straightly to advance strategy if the basics condition has not been well established. Company want things done faster all the time and addressing that the basic things is useless. According to Angeles (2009), there are 5 disciplines in Basic Maintenance Strategies which are:

i. Training and Education
ii. Maintenance Indices and KPI
iii. Autonomous Maintenance (AM)
iv. Basic Equipment Condition
v. Understanding of Preventive Maintenance

2.3.2 Intermediate Maintenance Strategy

This strategy can be implemented once the basic strategy has been established. According to Angeles (2009), there are 5 disciplines in Intermediate Maintenance Strategies which are:

i. Root Cause Failure Analysis (RCFA)
ii. Lubrication Strategy
iii. Reliability Initiatives
iv. Life Cycle Management
v. Spare Parts Management

2.3.3 Advanced Maintenance Strategy

Savings generated through the application of basic and intermediate strategy can be well spent on the acquisition of these technologies. According to Angeles (2009), there are 2 disciplines in Advanced Maintenance Strategies which are:

i. Condition-based Monitoring (CBM)
ii. Computerized Maintenance Management Systems (CMMS)

3.0 METHODOLOGY OF RESEARCH

The methodology of this project started from identifying the problem statement, selecting the case study to conduct, collecting and analyzing data, then proposes solution and makes conclusion. Figure 1 shows the detail flow chart of this project methodology.

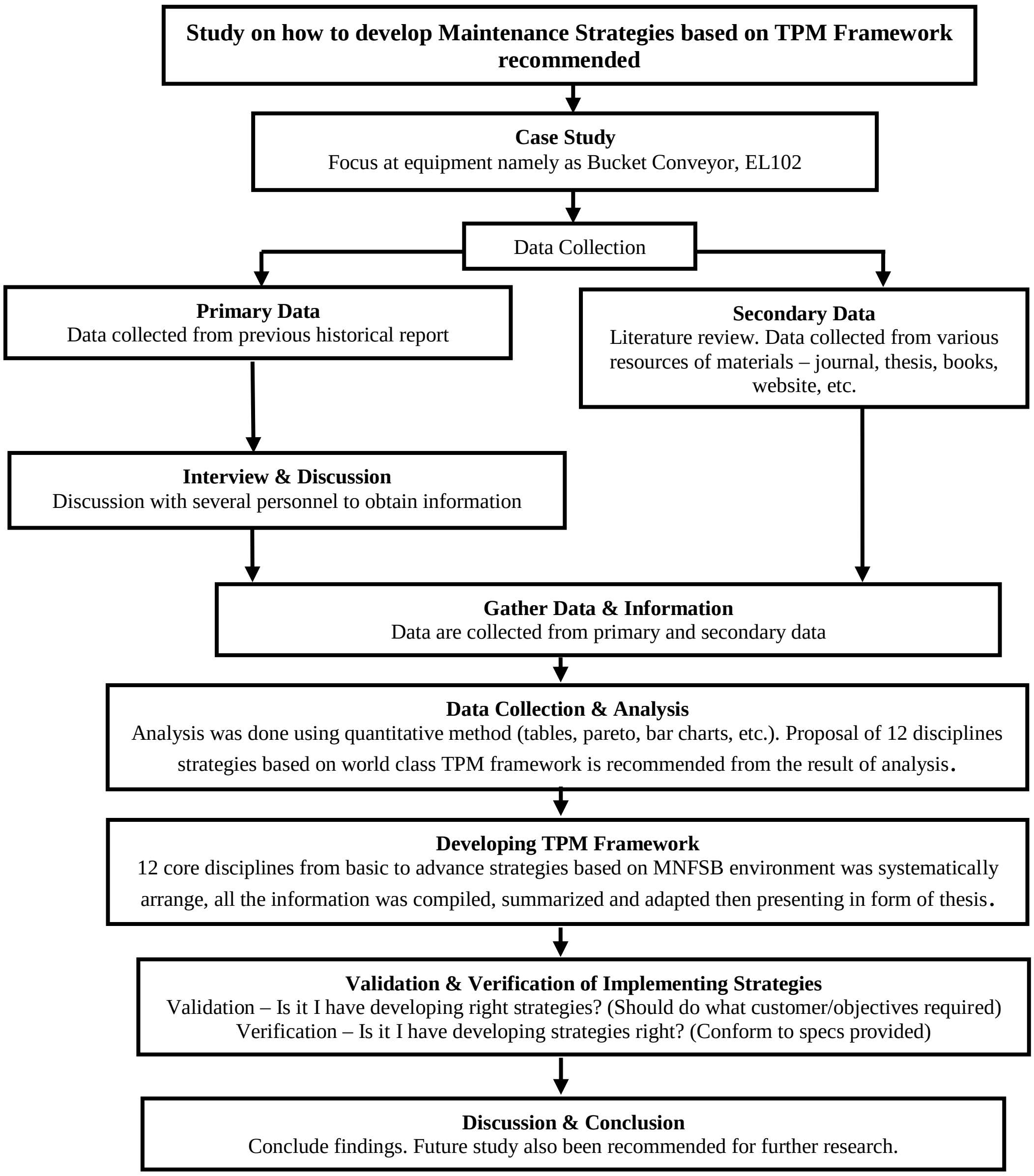


Figure 1: Flow chart for methodology of the project

Data collected was analyzed using quantitative methods. Data collected from various resources likes observation in plant, historical data recorded, interview and discussion session. The findings and way forward will be discussed in the following section.

4.0 PROPOSED FRAMEWORK

This section will analyze and describe detailed verification regarding the implementation of 12 core maintenance disciplines in order to become world class maintenance management system. As discussed in previous section, Bucket Conveyor EL102 contributes almost 375 hours or 7.4% downtime since plant commissioning. The conveyor already replaces twice in 5 years services. In order to achieve 14 hours/month target downtime set by management in 2011, proper plan should be made. This framework covers from basic to advanced disciplines.

4.1 Discipline 1 – Training and Education

The basic step is to train and teach all technicians on how to perform and handle the task given. For EL102, there are several selected training course that are related. Below stated a few training course attended by MNFSB technician and engineers after TPM program set up in:

a) Reliability Centre Maintenance (RCM) – This training is provided to engineer level. It is used to track and ensure types of maintenance activities performed. By attending this training, the engineer can estimate the lifetime of conveyor, roller, coupling, bearing, gearbox or pulley.
b) Root Cause Failure Analysis – This training is suitable for both levels - technician and engineer. It helps on how to discover failure using approaches such as 5-Why, Ishikawa Diagram, Fault Tree Analysis, FMEA and others. In modern maintenance practice, people want to know the root cause, not the probable cause of the problem.
c) Approach to Focused Improvement – This training is useful for both levels because it discusses on the step by step improvement analysis.

Other than the ones listed above, training on bearing technology, importance of conveyor preservation, lubrication strategy and understanding of rotating equipment are also important in maintaining EL102 condition.

4.2 Discipline 2 – Set Maintenance Target

To become world class maintenance, measuring maintenance performance is vital. Starting from year 2009, MNFSB has set Key Performance Indicator (KPI) to every staff, align with organization goals and direction. For EL102, equipment performance can be measured by:

a) Breakdown/downtime hours
b) Repair and maintenance cost
c) Types and no. of breakdown occurrences
    - Aging factor, repeated failure, etc.
d) Equipment availability,%
    - (Available time – Downtime)/Available time
e) Equipment utilization,%
    - (Loading time – Downtime)/Loading time
f) Equipment performance rate,%
    - (Ideal cycle time X output)/Operating time

g) Mean Time Between Failure (MTBF)
   - Operating time/Breakdown occurrence
h) Mean Time To Repair (MTTR)
   - Machine downtime/Breakdown occurrence
i) Mean Time To Fail (MTTF)
   - MTBF – MTTR

By measuring performance, one can determine which strategies, initiatives or activities that deserve additional focus and priority. Measuring performance can also indicate which equipment is within the budget and over the budget allocated. So it is easy for us to allocate budget wisely for the subsequent year.

4.3 Discipline 3 – Autonomous Maintenance

Autonomous Maintenance is based on education and training. It is about raising awareness of the operators on the knowledge and understanding principle operation of machines (Dhariya A, 2006). Equipment is always a shared responsibility for the two parties and not for the maintenance alone. Thus, there are some steps that can be done in order to help Engineering Department such as:

i. Sprinkle Phosphate Rock (PR) at edge of EL102 to preserve the conveyor from becoming wet. From our view, we suggest that PR can be sprinkle three times per day or once per shift. If the EL102 condition is dry, it can also prevent raw material become sticky at the cleat of conveyor. So, we indirectly reduce the load lower than necessary.
ii. Performs daily cleaning at bottom area and outlet chute. It is important to cleaning in bottom side of EL102 to prevent roller malfunction due to dust accumulate at floor area. Poor cleaning activity will cause abrasion to mechanical parts.

Engineering can escape from fire-fighting culture if operation accepting the role of Autonomous Maintenance. Once operators accept this role, maintenance can focus more on performing other maintenance strategies in their equipment. It must be understood that equipments' are shared responsibilities between operators and maintenance personnel.

4.4 Discipline 4 – Understanding of Basic Equipment Condition

World class industry understands the essence of establishing basic equipment condition in their equipment. Majority of catastrophic failures definitely can be avoided if operation and engineering works together towards common goal on addressing the basic equipment condition. For EL102, what basic conditions that we must understand are:

i. Clean – Keep the equipment clean as per standard. Inspection sometimes cannot be done if EL102 is in improper condition. Cleaning equipment means removing any forms of unwanted object from the equipment such as dirt, dust, scaling, grime etc. However, we must understand that MNFSB nature is different from electronic company. Cleaning for EL102 can be define as the conveyor is in proper state – no wet condition, all roller can function as usual, cleat in clean condition etc. If the cleaner can meet this entire requirement, it is easy for maintenance engineering to maintain it.
ii. Proper lubrication – Purpose of lubrication is to reduce friction for rotating mechanical parts such as bearing, coupling, gearbox etc. EL102 can be categorized as low speed of rotating equipment. So, lubrication for it is easy to manage. Just apply grease to each roller bearing at least once per week to prevent

bearing from become abrasive. It already stated in ISO requirement about time interval of replacing gearbox oil, greasing activities for bearing and so on.

iii. Detail inspection – It is importance for mechanical to do daily detail inspection for EL102. By doing this inspection, we can early address about leaking condition, misalignment, roller jammed, abnormal sound etc.

Major problem are always caused by accumulation of small things, however it often being ignored and neglected. Catastrophic breakdowns can be reduced if basic equipment condition is in place. Sometimes lack of bolting, loose bolt and screw and not sufficient tightening can lead to excessive vibration which then produces secondary damage to equipment.

4.5 Discipline 5 – Implementation of Preventive Maintenance

Preventive Maintenance is a basic maintenance performed on a schedule basis in order to extend the lifetime of equipment and endure the equipment meets their capacity required. It includes regular detail inspection, cleaning activities, planned component replacement, extensive overhauls and others. For EL102, there are parts that can be classified as certain types of failure shows in Table 2:

Table 2 : EL102 failure classification

Parts	Types of Failure	MTBF(estimate)	Cost of Parts	Quantity
Conveyor Belt	Age-related	3-4 years	RM 548,892	1 unit
Gearbox	Age-related	3-4 years	RM 9000	1 set
Coupling	Age-related	3-4 years	RM 6850	1 set
Head Pulley	Age-related	5 years	RM 10,500	1 unit
Tail Pulley	Age-related	5 years	RM 10,500	1 unit
Disc Roller	Random	3 years	RM 5500	2 pcs
Bend Roller	Random	1 year	RM 1480	6 pcs
Guide Roller	Random	1-3 months	RM 255	12 pcs
Carry Roller	Random	1-3 months	RM 1180	44 pcs
Return Roller	Random	1-3 months	RM 1075	76 pcs
Impact Roller	Random	1-3 months	RM 1180	4 pcs

Correct frequency of parts replacement will a good strategy suited with age-related and random failure. The goal of preventive maintenance is to anticipate, prevent, prolong or delay the process of failure from occurring. One step to become Proactive Maintenance is successful implementation in Preventive Maintenance activity.

4.6 Discipline 6 – Spare Parts Management

Spare parts management simply means that acquiring the right parts at the right times when maintenance needs it. Most of the problems occur in organization related to spare parts management are disorganized storeroom/warehouse, inaccurate inventories and obsolete parts are still being ordered. At MNFSB, spare parts are controlled by Logistic section. One important issue is open line communication between both parties, Logistic and Engineering. Centralized warehouse is being used by the company. By having centralized warehouse, it is easy to monitor and control the spare parts availability. For EL102, spare parts that need to be ready shows in Table 3.

Table 3: EL102 spare parts availability

Parts	**Status**	**Remarks**
Conveyor Belt	Have 11m portion c/w side wall	Just store in case of conveyor tear off.
Gearbox	No spare parts	Need to order 1set
Coupling	Yes	Have complete 1set. Need to do boring.
Head Pulley	No	Make-to-Order if they are plan to replace
Tail Pulley	No	
Disc Roller	No	
Bend Roller	Spare parts ready	Need to spare at least 6 pcs
Guide Roller	Spare parts ready	Need to spare at least 6 pcs
Carry Roller	Spare parts ready	Need to spare at least 20 pcs
Return Roller	Spare parts ready	Need to spare at least 30 pcs
Impact Roller	Spare parts ready	Need to spare at least 4 pcs

* Data taken until 31 March 2011

The common question raised for spare parts management is what parts need to store and what is the amount required for each part. Historical records can provide us information on parts that need to be stock and will be on a need-to-have basis. Parts that are listed in Preventive Maintenance lists should be stocked in warehouse. Critical parts and parts that acquired amount of time to order also need to be stored. The best way to know the quantity of parts that need to be ready in storeroom is by monitoring the trend of parts movement.

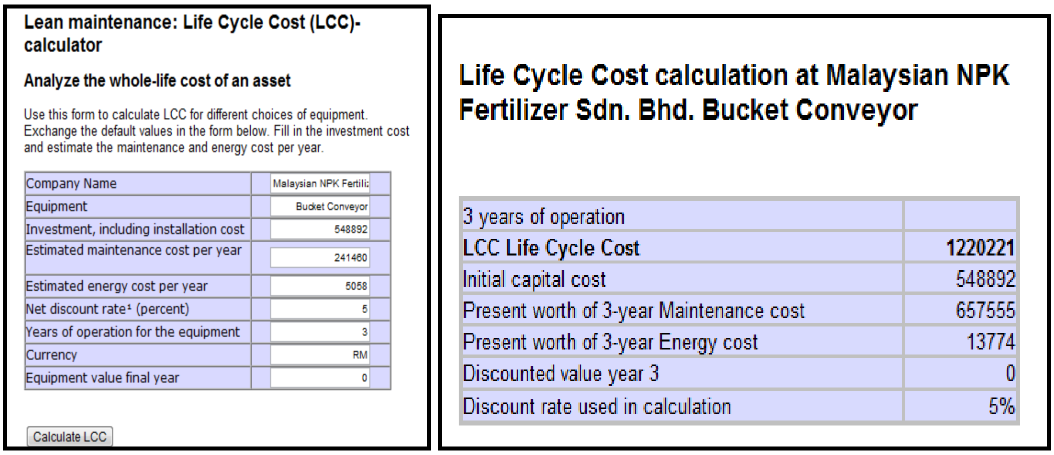
Computerized system will help a lot regard to this matter. In MNFSB, all parts that are use or taken out by user, will be re-order by logistic. As this plant already establish almost 6 years, re-analysis of amount of spare parts required is necessary.

4.7 Discipline 7 – Life Cycle Management

Total cost of equipment is started from the machine design until it is out of service. The best way to reduce the costs is by understanding Life Cycle Cost (LCC). To calculate LCC for EL102, there are some data required as listed below:

i. Equipment + installation cost = RM 548 892 (average 3times replacement)
ii. Estimate maintenance cost per year = RM 241 460 (gearbox, roller, pulley, etc.)
iii. Estimate energy cost per year = RM 5 058 (High Voltage Industrial Tariff - E3s)
   - 15kW/day X 24hrs X 30days X RM28.10 X 12mth = RM 5 058
iv. Net discount rate = 5% (estimated)
v. Equipment lifetime = 3years
vi. Equipment value final year = RM 0
   - The value is RM 0 because the rubber is synthetic rubber. So, scrap will classify EL102 conveyor belt as a junk.

The data entered is shows in Figure 2.



Lean maintenance: Life Cycle Cost (LCC)-calculator

Analyze the whole-life cost of an asset

Use this form to calculate LCC for different choices of equipment. Exchange the default values in the form below. Fill in the investment cost and estimate the maintenance and energy cost per year.

Company Name	Malaysian NPK Fertili
Equipment	Bucket Conveyor
Investment, including installation cost	548892
Estimated maintenance cost per year	241460
Estimated energy cost per year	5058
Net discount rate¹ (percent)	5
Years of operation for the equipment	3
Currency	RM
Equipment value final year	0

Calculate LCC

Life Cycle Cost calculation at Malaysian NPK Fertilizer Sdn. Bhd. Bucket Conveyor

3 years of operation	
LCC Life Cycle Cost	**1220221**
Initial capital cost	548892
Present worth of 3-year Maintenance cost	657555
Present worth of 3-year Energy cost	13774
Discounted value year 3	0
Discount rate used in calculation	5%

Figure 2 : LCC calculation for EL102

The analysis shows that LCC for EL102 is RM 1 220 221 in 3 years of operation. The biggest costs lie in how the equipment is maintained. By doing this analysis, now we can calculate the savings either in operating or maintenance costs.

After doing this analysis, it proves that Purchasing department cannot look entirely at cheapest parts, but need to look further on LCC which also cover running costs. By considering only initial cost is like seeing the tip of iceberg. Maintenance should focus on improving reliability, not on reducing cost because if reliability starts to improve, then cost will definitely go down.

4.8 Discipline 8 – Lubrication Management

Lubricants are design to reduce friction and wear between contacting surfaces (Mang, 2007). It is means that to reduce friction between rotating contact surfaces, area of contacted should be lubricated. For EL102, the lubrication activity is very simple. It is because this equipment is slow speed types. All the lubrication activities already embedded in ISO requirements. Table 4 shows the activities of lubrication for the EL102.

Table 4: EL102 lubrication activities

				Month											
Parts	**Types of Lubr.**	**Amount**	**Interval**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Bearing	Shell Alvania EP2	0.23 kg	3 month	##			##			##			##		
Gearbox	Shell Omala 220	37.0 L	6 month			@						@			
Coupling	Shell Alvania EP2	3.4 kg	3 month	##			##			##			##		

Remarks: ## - Greasing @ - Oil

Even though the lubrication activities already set in ISO requirements, detail inspection for it should be done daily. WD40 is use to apply spray lubricant to roller bearing if there produce abnormal sound or seems roller tends to fail. WD40 also use for EL102 to prevent corrosion to roller bearing.

4.9 Discipline 9 – Value of Reliability

Reliability is the probability that a machine part or product will function properly for a specified time under stated condition (Blank, 2004). Most of companies today focus on productivity, quality and safety in their daily operation. Nobody cares about reliability.

Reliability of equipment can be enhanced by two ways which are improving individual components or provide redundancy to it.

For EL102, it is well known as one of the critical equipment at MNFSB. If the equipment fails, the plant will stop due to no raw material send to process plant. Refer back to Table 4.1 (EL102 failure analysis), there are 10 core parts that are heavily used for running EL102. All of the equipment already improves in terms of specs from time to time. For example, EL102 belt has been improved from abrasive resistant specs to oil resistant specs in order for it to carry oily contents of raw material in future. Gearbox is ready made, cannot be improved anymore unless management decide to increase the capacity. Coupling can be improved by using rubber/spider coupling instead of gear coupling. If the coupling fails, the rubber will fail first and produces abnormal sound. So maintenance people only need to replace the rubber set rather than replacing the whole coupling set. Reliability of head and tail pulley only can be improved by upgrading the quality of internal bearing used and rubber lagging feature. This improvement also applies to all types of roller stated in Table 4.1.

The second ways to improve reliability is by providing redundancy to system. For EL102, currently there is no redundancy provided to the equipment. If this equipment fails, plant will stop. Management already decides to install backup for EL102 which the system call bucket elevator. The discussion is still ongoing regards to this matter. By improving reliability of equipment, it will reduce the cost of maintenance. Reliability cannot be achieved by cutting costs but improving reliability will definitely reduce maintenance and operating costs.

4.10 Discipline 10 – Root Cause Failure Analysis

Root Cause Failure Analysis (RCFA) is used to understand the core reason of problems. It is not a tool to fully eliminate equipment failure by overhaul, repair or replace new equipment, but we could prevent from reoccurrence of the problems by analyzing through RCFA. By doing RCFA, at least we can prevent or predict the timing of failure (MTBF). RCFA can anticipate, delay, prolong or control the process failure. There are several tools can be used to do RCFA likes Fishbone Diagram, FMEA, Pareto Analysis, Fault Tree Analysis and others. Maintenance people traditionally have culture to have fast solution by jumping into repairing and modification without knowing or tackle the root cause of problems.

For EL102, there are several times of failure occurring since plant commissioning. However, there are no RCFA documentation has been done during this 5 years period. Maybe lacks of training or knowledge and culture of nature regarding this matter makes MNFSB not get on into RCFA when problem occur. Start from 2010, RCFA start to be implemented after instruction from management aligns with our TPM initiatives. All major equipment problems need to submit abnormalities report with an RCFA attachment.

Quick troubleshooting is no longer an effective strategy to world class organization. In today’s competitive world, an activity for RCFA if the equipment fails must be a priority.

4.11 Discipline 11 – Condition Based Maintenance

Condition Based Maintenance (CBM) is an advance strategy for any organization towards world class maintenance. It is very difficult to see the achievement if the basic and intermediate discipline was ignored. Some investment needs to spend in order to explore this advance maintenance strategy. It is because for establish this strategies, several instruments needs to acquire. CBM is design to enhance current practice of Preventive Maintenance in a plant. Due to human sense are limited, CBM will further look into the equipment with the aid from diagnostic measuring instruments to get better result.

There are several CBM instruments that are used in MNFSB currently likes probe connect with panel board on top of every high speed rotating devices likes fan to detect bearing vibration, Infrared Thermograph to detect poor electrical cable connections, short circuits and overloads, Stroboscope to check high speed rotating equipment by freezing it at certain speed, thus detect any belt looseness, pulley misalignment and bolt missing and micro-log for Vibration Monitoring Application. Vibration analysis is one of the most common types of predictive maintenance techniques. It is used to analyze the plotted vibration signals for the equipment. It can show results like shaft related faults, imbalance condition, bearing damage, structural looseness and eccentricity problems. EL102 is a low speed rotating equipment. So, EL102 is not directly related to this entire advance instrument.

4.12 Discipline 12 – Computerized Maintenance Management System

The role of Computerized Maintenance Management System (CMMS) is to automate the maintenance daily activities process. CMMS application can improve many aspects likes monitoring balance of spare parts, control triggers, assist and predicting future needs, studying critical parts lifetime based on parts replacement and so on. The role of CMMS also must be apply to whole departments likes purchasing, warehouse, operation, logistic and operation.

For EL102, CMMS is not utilized at all. Engineering department used CMMS just to check the spare parts availability. Our software doesn’t have any analysis regarding MTTR, MTBF or OEE embedded to the system and it is not compatible to use anymore for our organization due to no updated features implanted in the software. It is likes any today’s computer which still used Windows 95. Otherwise, if organization wants to establish CMMS in their organization, a focus person is a must.

5.0 DATA COLLECTION AND ANALYSIS

Data of equipment breakdown was collected from mechanical section in engineering department starting from 2005 until 2010. Figure 3 shows bar graph for mechanical equipment downtime since plant commissioning in 2005 until 2010.

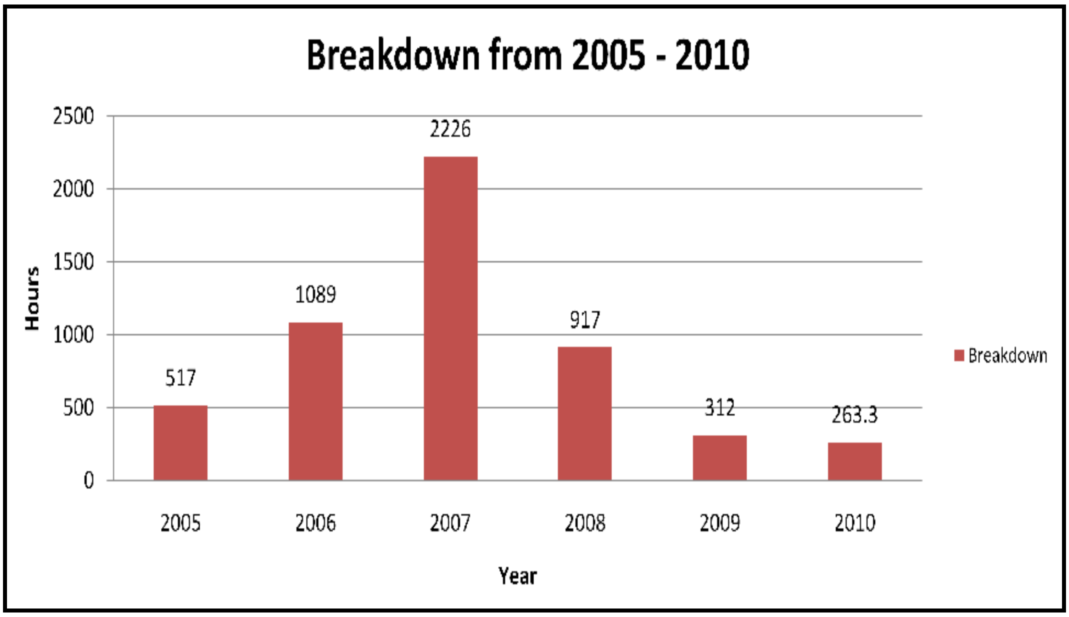


Figure 3: Mechanical equipment downtime from 2005 to 2010

As shows in the bar graph above, 2007 was the highest recorded downtime for mechanical section, total to 2226 hours, followed by 2006, 1089 hours and year 2008, 917 hours downtime. 2010 recorded the lowest downtime for mechanical section since plant commisioning, which contributed only about 263.3 hours followed by 2009, 312 hours downtime. In 2007, after all the MNFSB main contractor was ended their service contract, the downtime shoot up double compare to the previous year. It shows that, lack of knowledge in troubleshooting an equipment, can lead to higher downtime to plant and equipment.

Downtime seems reduce start on year 2008 onwards. One of the reason is because management decided to re-appoint one of the leader during MNFSB is under service contract staff. Others, management also add several experience technician for mechanical section to strengthen the section from 10 personnel in mechanical section in 2005 to 14 personnel in 2010 including engineer. TPM kick-off at MNFSB start from 2009. Detail equipment inspection start this year align with Preventive Maintenance (PM) pillar in TPM initiatives. Start from 2010, each technician have been given specific area to be concern for such as piping, conveyor, drum, screen and others. After more than 5 years running the plant, operation site also have gain some knowledge about equipment capability and limitations. They always ask for advice rather than force running equipment that seems to be abnormal. It actually help mechanical section to reduce unplanned equipment breakdown. Others, there are also introduction of bi-weekly planned shutdown since end of year 2009 until 2010. In 2011, we plan to do plan shutdown on 3weeks interval basis. Before 2009, shutdown is done on once a month basis. Start from 2011, MNFSB want to move on to another destination which is called World Class Maintenance Management System in Total Productive Maintenance (TPM). Some of the training already have been done in 2010 such as Importance of 5S, Autonomous Maintenance and others.

In MNFSB, there are about 80 rotating and static equipment such as conveyor, crusher, screen, drum, bucket elevator, bucket conveyor, fan, pump etc. All of this equipment contributes to machine downtime. Pareto Chart will be construct in order to identify the most critical equipment that contribute to machine downtime. Figure 4 shows Pareto Chart for percentage of 37 machines that contribute to downtime from 2005 until 2010.

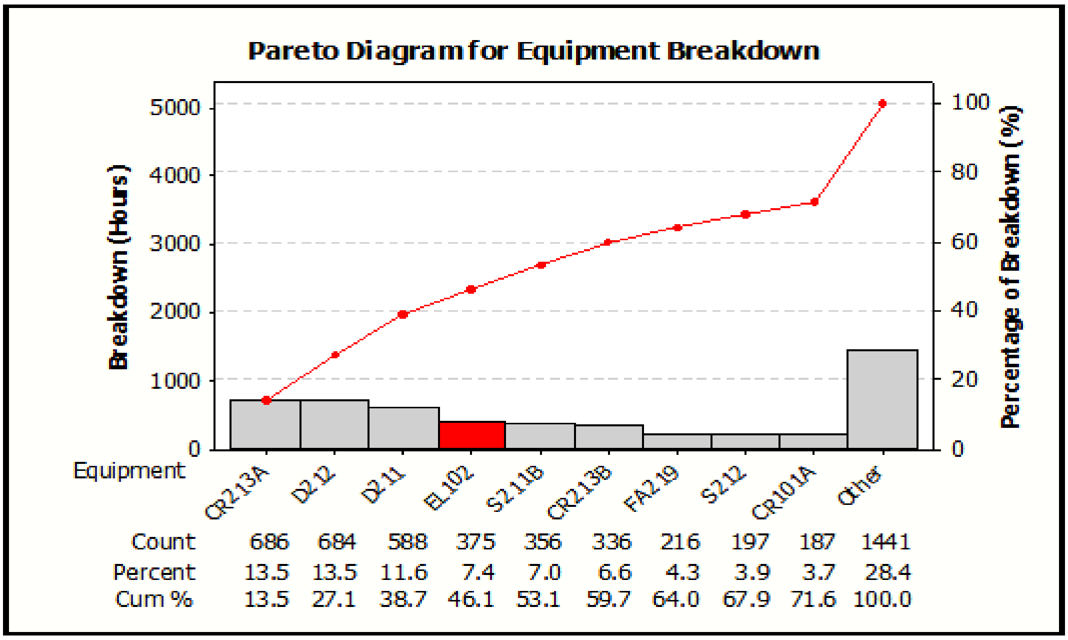


Figure 4: Pareto chart for mechanical equipment downtime from 2005 to 2010

From the Pareto Chart, it shows the most critical model that contributes to the highest downtime was CR213B, followed by D212, D211, S211B, EL102, CR213A and so forth. EL102 contribute almost 7.4% downtime during 5 years plant operates. EL102 was selected as a case study although the equipment is not the most critical downtime contribution because:

i. CR213B - Highest downtime for CR213B occur because there are problem on crushing efficiency and activity for replacing roller on year 2008. After that, all replacing roller activity was only done during annual Turnaround events. So, the downtime is not significant for the improvement analysis because it is not repetitive failure. It is more about internal factors rather than proper planning.
ii. D212 - Highest downtime for D212 occur because there are problem on fluid coupling on year 2006 (600 hours downtime) and at that time, there are no spare part for fluid coupling. Until 2010, those types of breakdown do not happen again. So, the downtime is not significant for the improvement analysis.
iii. D211 - Highest downtime for D211 occur because there are activity on replacing rubber panel that contribute almost 463hrs since 2005 until 2008. After improving the quality of rubber, until now, that types of breakdown do not happen again. So, the downtime is not significant for the improvement analysis.
iv. EL102 – This is recent and repetitive failure. Downtimes happen on 2005, 2007, 2008 and 2010. After so many improvement we already made during this period, the failure still occur. Rubber quality is not an issue because only one manufacturer supplies this bucket conveyor. MNFSB can order the material from super high quality rubber manufactures likes Bridgestone, Yokohama or Goodyear Rubber but the return of investment taken so many years. So it can be considered as non-valuable investment in terms of financial. In order to pro-long this bucket conveyor lifetime is by having proper planning of maintaining it.

In 2010, target downtime for mechanical section setting by management was 17 hours/month based on 2009 downtime basis. Although there is a lot of reduction in downtime year-to-year, 2011 bring a new challenge to achieve target downtime. Downtime target set by management for mechanical section in 2011 was 14 hours/month. In order to achieve 2011 target, proper plan need to be done. All mechanical personnel need to be focus on maintaining equipment either normal crew or shift.

Employees must be educated and convinced that TPM is not just another "program of the month" and that management must totally commit to the program and the extended time frame necessary for full implementation. This project will bring 12 disciplines as a core framework to the efficient planning in order for MNFSB to achieve world class maintenance management system.

6.0 RESULTS AND DISCUSSIONS

6.1 Review of Achievement

The validation for this project was done by referring to the project objectives. The objective of this project is to reduce downtime by 50% for Bucket Conveyor (EL102) from 62.5 hours in 2010 to 31.25 hours in 2011 within 3 months period (January 2011 to March 2011) via introducing 12 disciplines as a framework for Total Productive Maintenance (TPM) initiatives. Table 5 shows the summary for the 3 months of 2011 downtime data.

Table 5: Summary of downtime data for EL102 in early 2011

MONTH	DATE	DOWNTIME	FAILURE DESCRIPTION
January	10/1/2011	12.5 hrs	Repair torn of bucket elevator
February	**NO BREAKDOWN**		
March	**NO BREAKDOWN**		
EL102 Total Breakdown		**12.5 hrs**	

Looking towards the objective stated, target downtime for EL102 is 31.25 hours for year 2011. Until March, the downtimes recorded only achieve 12.5 hrs. It means that there are 60% target downtime left for EL102. Higher downtime recorded for January 2011 is due to the 20 meter portion of bucket conveyor still not arrives at MNFSB. After replacing it on Mini Turnaround on February 2011, it shows that is no downtime occurs afterwards. However, the framework proposed is validating to the objective stated.

6.2 Cost Benefit Analysis

Cost benefit analysis is a term that refers to assess the project or policy created to make decision based on economically approach. It will determines how well is our plan goes in terms of financial concern. The production cost of losses is calculated by using formula below:

$$\text{Unit Cost (RM)} \times \frac{\text{Prod. Output in a Year (tone)}}{\text{8760 hrs}} \times \text{EL102 downtime (hrs)} \qquad (1)$$

Detail analysis on production cost of losses as shown in Table 6.

Table 6 : Production cost of losses from 2005 until March 2011

Year	Unit Cost	Production Rate	Downtime for EL102
2005	RM 240 / ton	20 ton/hr	196 hrs
2006		21 ton/hr	-
2007		19 ton/hr	7 hrs
2008		19 ton/hr	97 hrs
2009		27 ton/hr	10 hrs
2010	RM 355 / ton	25 ton/hr	62.5 hrs
3/2011		25 ton/hr	15.5 hrs
TOTAL RM Losses			**RM 2 172 090**

Total production losses due to EL102 breakdown are reaching almost RM 2.2 million. It is a huge amount of money. Target downtime for EL102 in 2011 is 31.25 hours instead of 62.50 hours recorded in 2010. If EL102 can achieve the target, the RM losses will be reducing half from last year, which savings almost RM 277k of money. Low costs of losses are always a product of good maintenance and operation practice.

Due to management want to improve the reliability of EL102, they decide to do backup as a redundancy for the equipment. The construction of backup EL102 is planning to be completed on July 2011. It will improve the reliability of EL102 afterwards by providing redundancy.

7.0 CONCLUSION AND FUTURE RESEARCH

Today, most industries have ambition to become world class organization. Most of industries not born as world class organization but transition from reactive to proactive are vital to compete in today's world. Fire-fighting syndrome, shouting, hero stuff, stop-the-bleeding syndrome and pressure management must be left out in today's world of maintenance. A journey to world class maintenance must be done on a wide approach which covers totals employees in the process. A lot of resistance needs to be passing through.

Based on the problems, methodology is prepared to establish a plan towards world class maintenance management system. Numerous books, journal, websites and thesis have been reviewed to give some insight towards progression of this project. The historical downtime data is then analyzed to uncover breakdown hours occur in MNFSB by using several tools such as Bar Graph and Pareto Chart. After conducting several analyses, a framework would enable MNFSB to be world class maintenance management system refers to the 12 disciplines stated that cover from basic to advance disciplines had been proposed.

The verification is important to provide some knowledge on how to embed the disciplines to the real application. Validation of the project is done in the subsequent section to prove that the framework is valid to the objective declare. Financial analysis is done to show amount of RM losses due to equipment breakdown.

There are two recommendations, first by applying all these maintenance disciplines to equipments other than EL102. Thus, we can see some potential cost savings regards to this matter. Second, by focusing only one discipline and apply it to a specific process flow. By doing this, it suppose to see some sort of improvements in terms of reliability of equipment.

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