GRADUATION PROJECT

Research Report

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An improved Preventive Maintenance process

by
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Abstract

Research motives

Preventive Maintenance (PM) is a maintenance policy to optimize asset availability and reliability. Unplanned downtime has a big impact on the throughput of the production. This especially counts for a complex refinery as Shell Pernis, where enormous volumes of throughput are processed inside and between the plants. Non-compliance with PM tasks, determined by reliability studies, could result in economical and HSE consequences for Shell Pernis. The PM process that is in place in Shell Pernis is not well-structured, organized and standardized. Furthermore, no clear strategy is set up to close the performance gap between the current and desired PM/CM (Corrective Maintenance) financial ratio of 80/20. This leads to the following research question:

What end-to-end process does Shell Pernis need towards an improved Preventive Maintenance strategy?

Approach

Starting with defining the As-Is situation by means of Sharp and McDermott's theory (Sharp & McDermott, 2009). Following and applying suggested improvements ultimately pointed the way to a new PM process in the To-Be situation. Heading to this To-Be situation required determination of an implementation, execution, evaluation and rebound plan (Deming, 1950). This was piloted on one production unit. For further development of an improved PM process a strategy is set where the goal is firstly identified. The strategy that the PM process needs is defined by stating the strategic goal. The difference between the current PM/CM ratio and the desired PM/CM ratio is the performance gap that needed to be closed. This was done by constructing the strategic mission (Márquez, 2007).

Results

The PM process

The main findings in the As-Is situation can be summed up into four parts.
1: The reliability study results are often incompletely delivered to Maintenance Execution.
2: The preventive plans are incomplete without any standardization and existing preventive plans are often double, incorrect, incomplete or redundant.
3: There is a lack of control points within the process where mainly the assurance by Reliability Engineering is missing.
4: There is an absence of proper feedback loops to guarantee any form of continuous improvement on preventive plans.

The major changes that are established when designing the To-Be situation are to cover the issues that the As-Is situation contains.
1: An intelligent tool and database that secures correct delivery of study results and contains a check on correctness of the translation of study results into preventive plans.
2: Changing the Roles and Responsibility of the Preventive Planners. The Preventive Planner makes a fully completed preventive plan that meets the right standards and features all information that is needed to perform smooth work order preparation. Next to this a check is done by the Preventive Planner on called work orders which will also be done in the reintegrated meeting to review performances.
3: Control points in the process by the Sr. Planner and assistant Operational Maintenance Coordinator on work orders and assurance of the Reliability Engineering by evaluating written history by sample and annually based on the Bad Actor Process.
4: Implementation of the feedback loops:

- A. Changes in the work order, directly to the Preventive Planner
- B. Feedback regarding practical issues (e.g. scaffolding, isolation, crane etc.) from PM execution, directly to the Preventive Planner
- C. Feedback regarding study contents delivered via an intelligent tool and database.

The PM strategy
Currently Shell Pernis has a financial ratio close to 68/32 of PM/CM. O'Brien's theory (O'Brien, 2013) and Smith's theory (Smith, 2012) affirm that the financial ratio of PM/CM should be 80/20.
This means a 12% performance gap between the current situation and the desired situation. The strategic goal is therefore set as:

Getting the ratio between PM and CM expenses from ± $\frac{68\%\ PM}{32\%\ CM}$ to $\frac{80\%\ PM}{20\%\ CM}$ by closing the performance gap of ±12%.

This will be done fulfilling the strategic mission (Márquez, 2007). The mission contains of:
1: A clean-up of existing plans
2: PDCA principle on application of the new process
3: An innovational policy where operational utilization is the basis of PM.

Contribution
This graduation project has given Shell Pernis the following deliverables:
- An improved PM process where the loop is closed with the PM scope supply process (Living Program).
- An intelligent tool to increase efficiency of the closed loop between RCM Living Program and Maintenance Execution.
- Assurance and control points to minimalize mistakes and to secure good translation of reliability studies to PM plans.
- Implementation of the improved PM process that is piloted on one production unit, this leads to an implementation plan that is applicable for the rest of the seven production units.
- A strategy that sets out a vision and mission for the specific strategic goal regarding PM at Shell Pernis.
- Several documents which Shell Pernis' maintenance organization can stick to in the future as they are all stored on the PM web page of Shell Pernis' intranet. The documents are:
  - A step-by-step work instruction of the new PM process
  - A manual for the Living Program tool
  - An official and professional procedure that meets Shell standards

Conclusion
The loop between Maintenance Execution and the Living Program is now closed because assurance from Reliability Engineering is added to the PM process. Due to the implemented feedback loops and control points continuous improvement of the PM plan quality is guaranteed. These two aspects deliver Shell Pernis the possibility to develop their PM performances. This will contribute to optimization of asset availability and reliability. The improved PM process improves the PM task compliance which will result in a decrease of unplanned downtime.
The improved process is more efficient as well as the work repeatability is reduced because of the improvement in the Preventive Planning and because of the continuous improvement of the PM plans.

A clear strategy is set that will contribute in closing the performance gap. Shell Pernis will grow to the desired 80/20 financial ratio of PM/CM by applying the strategic mission for PM. Shell Pernis should first clean up their existing PM plans in their system. When this is done Shell Pernis should implement the new PM process on all production units. The new process should be continuously assessed to guard the performance level. Long-term objective for PM is to merge Operations' equipment utility and PM to further optimize PM at the refinery of Shell Pernis.

Acknowledgement

After many days on the sixth floor of the Central Office of Shell Nederland Raffinaderij B.V., Pernis-Rotterdam (Shell Pernis) and what seemed to be endless hours of travelling by car from Zierikzee to Pernis this project ultimately came to a successful end. This project was a graduation project for the Bachelor of Engineering program *International Maintenance Management*. I have followed this program for the past four years. These four wonderful years, which I have truly enjoyed, were finalized by this project with *preventive maintenance* as main subject. Preventive maintenance is often seen as a high expense rather than an investment which could deliver big financial benefits. This however, was not the case at Shell Pernis. It was therefore not least for this reason that I had chosen this company to perform my graduation project at. Besides, based on previous experiences I knew their big concern of maintenance because of huge dependence on available equipment because of extreme operational throughput. This really added significance to this project and so motivation for me as an individual.

Although this will sound cliché, I was never able to accomplish this project without the help of many people in and outside the maintenance organization of Shell Pernis. The willingness and helpful behavior of many is something I am very thankful for. I would specially like to thank Linh Ta Cam (Maintenance Excellence Supervisor) as my In-Company Supervisor of this project. Despite a fully loaded agenda she always took the time for me to support, advice, guide and interrupt whenever needed. She really made this project feel like an important one for me, as it actually was for the Maintenance Excellence department.
Flip Wubben, 1st examiner, definitely requires to be mentioned also as he has always delivered constructive feedback on my deliverables any moment I asked for it.
Big thanks as well to Jeroen Jansen (assistant Maintenance Supervisor ROM) as facilitator of the project. His contribution, interest and help, often on his own initiative, where very valuable.

Highly important for this project where the Preventive Planners, Fred Groenewegen, Andre Noordzij, and Rene van Ginkel, as they play a major role in the process of preventive maintenance. I would therefore like to thank them for taking their time, effort and having the patience when explaining something to me again and again even though this project resulted in a somewhat higher workload for them. In terms of support in any mean of the word I owe a lot to Koos den Braber (Work Process Integration Lead), Ger van Tussenbroek (RCM Focal Point) and Bert Boer (SAP Super User). They have helped me whenever I thought I needed it. Last but not least, I would like to show my gratitude to all participants scattered over all PUs of Shell Pernis that cooperated during the interviews and attended meetings and sessions. I would like to mention in particular the participants of the maintenance department of the ROM, principally Marco Bakker, as they cooperated and helped me very much during the implementation phase of this project.

To finish, I would like to mention that I have felt like an important member of a business improvement project rather than a temporary intern, which is in my opinion something special.

Zierikzee, 2016
Jorick Machiel de Vries

List of abbreviations

BBS	Bedrijfs Beheer Systeem
BFD	Basic Finish Date
BSD	Basic Start Date
CM	Corrective Maintenance
CP	Corrective Planner
CUI	Corrosion Under Isolation
EI	Equipment Integrity
FLOC	Functional Location
GAME-ME	Global Asset Management Excellence - Maintenance Execution
HEMP	Hazard and Effects Management Process
HSE	Health Safety and Environment
IPF	Instrumental Protective Functions
KPI	Key Performance Indicators
LTLP	Long Term Living Program
MCMP	Maintenance Complete (Work order status)
ME	Maintenance Execution
MRE	Major Rotating Equipment
MTLP	Mid-Term Living Program
NSI	Niet Stop-gebonden Inspectie
OMC	Operations Maintenance Coordinator
OTM	Operational Task Management
PDCA	Plan Do Check Act
PM	Preventive Maintenance
POR	Preventief Onderhoud Review
PP	Preventive Planner
PU	Production Unit
RBI	Risk Based Inspection
RCM	Reliability Centered Maintenance
RDU	Refinery Distillation Units
RE	Reliability Engineer
ROM	Refinery Oil Movements
RTA	Refinery Treating & Alkylation
RVC	Refinery Vacuum & Cracking
RWH	Refinery Waterfront & Hycon
SBKD	Site Brandweer en Kantoordiensten
WAPP	Work Order Approved (Work order status)
WOIP	Work Order In Process (Work order status)
WOPR	Waiting on Operations
WRTA	Work Order Ready to Approve (Work order status)

Contents

1 Introduction

For many years Shell Nederland Raffinaderij B.V., Pernis-Rotterdam, hereafter called Shell Pernis, is standing on one of the top spots when speaking of complex crude oil refining operations. One would almost forget how much a refinery as Shell Pernis rely on proper functioning technology. Without the application of professional maintenance it would not be possible to manufacture the huge amount of fuels provided to the consumers in a worldwide petrochemical market. Maintenance that prevents functional failures, which potentially result in forced production stops or health, safety and environmental (HSE) threats, is even more significant. It is called preventive maintenance (PM) and whenever well-integrated it is an investment which will definitely deliver credible benefits for any asset owner.

For this very reason this graduation project has started to improve and optimize the PM process of Shell Pernis. This project tries to solve the problem furtherly explained in the next section of this introductory chapter.

1.1 Problem statement

Within Shell Pernis, the ratio between preventive and corrective maintenance is economically not optimal. This is concluded out of a classified financial report from Shell Pernis' finance department and out of Solomon reports, classified as well. Currently, still too much money is spent on corrective maintenance (CM) which should be avoided. Actually, there are preventive plans available at the Shell Pernis which are stored in the ERP system GSAP. These PM plans are based upon studies performed by Reliability Engineers (RE). Those studies are RCM, IPF, RBI and others (read more about the studies in chapter 3). Preventive plans should enable Shell Pernis to dose or prevent CM by applying PM correctly. The problem however can be formulated as follows: Until today the available preventive plans are not applied according to an end-to-end process which means there is no closed loop with output and input. Furthermore, the process is not standardized for every production unit. Besides, no check is implemented on executed PM to ensure quality. The reason behind these problems is that there is no clear strategy/vision within Shell Pernis on how to apply PM.

Clearly, the end-to-end process that is missing should provide that the right PM is executed on the right equipment. Besides, a feedback has to be present to warrant if the performed PM indeed delivered desired results. This project will be performed within the Maintenance Excellence department of Shell Pernis where currently individual members of this team are working on this case. The graduation project entails to pick this up, to connect current activities and to set direction in solving this problem.

1.1.1 Problem analysis

As the problem definition is provided an answer is required on the question why it is actually a problem. The reason why Shell Pernis does not have an end-to-end process is because there is no central norm or standard available on how to apply the PM process. This is a problem because Shell Pernis needs a standardized end-to-end process to develop the PM process in the future. Because of the economically non-optimal ratio between PM and CM Shell does face financial problems according to classified reports and Solomon reports. The strategy which is currently missing therefore solves the financial problems regarding PM. That makes this research an urgent research for Shell Pernis according to the Maintenance Excellence Supervisor.

1.2 Research question

The main subject of this research is the effective application of PM. Since the aim of this research is to find out what strategy is required for Shell Pernis to apply PM effectively and how it should be executed in a process to achieve effectiveness the main research question is stated as:

What end-to-end process does Shell Pernis need towards an improved Preventive Maintenance strategy?

In order to find a credible answer to the main research question more detailed sub questions are formulated. Some of the sub questions deliver a professional product as a project deliverable for Shell Pernis. Read more about those products in chapter 3. The sub questions are classified to one of three different parts. An overview is given below.

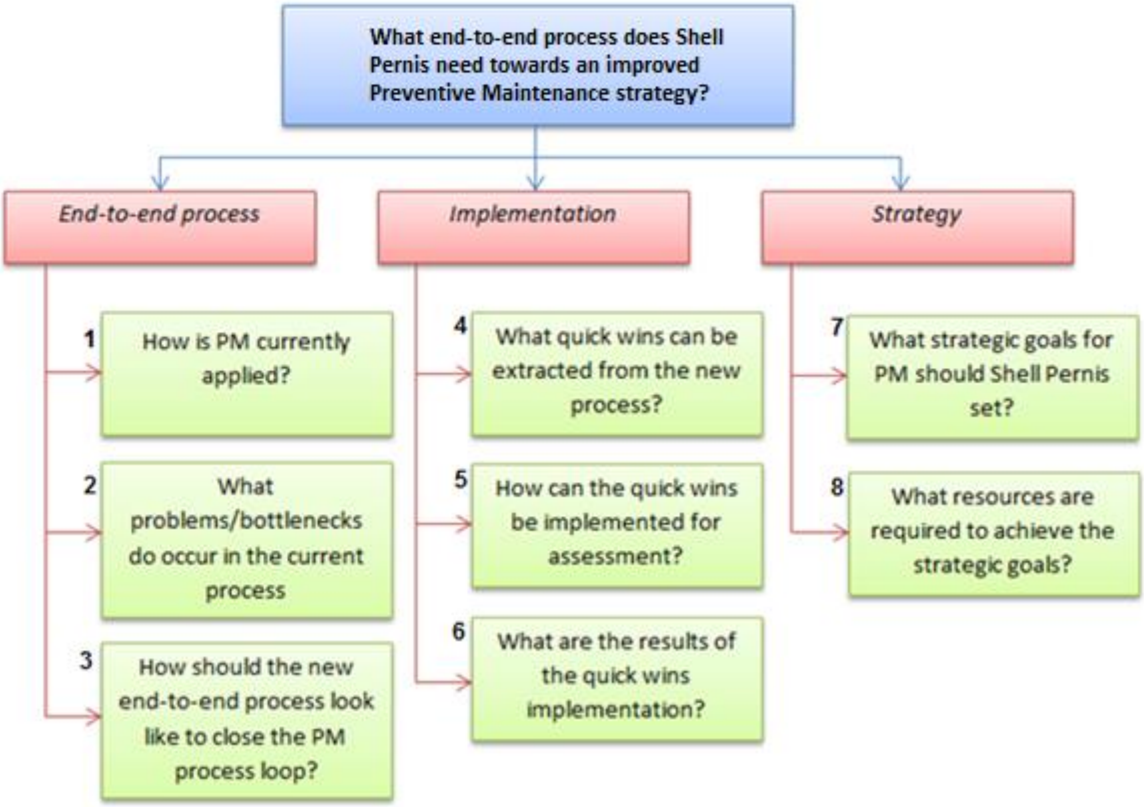

Figure 1. Research question structure

1.3 Research Method

This research will be performed by answering the sub-questions and ultimately the research question by a solid structure. In figure 1 the research structure is shown and as can be seen it is divided into three parts; Analysis of the process, Implementation of the process and the strategy.
Besides dividing the research structure in three parts, the questions are also differently answered in terms of methodologies.
Two different types of questions indicate how the answer is given. These are:
Empiric: Answer is extracted from performed field research. (Verhoeven, 2010)
Analytic: Answer is extracted from theoretical research and field research. (Verhoeven, 2010)

In the overview below a clear explanation is given on sort of question, the method and validation.

#	Sub-question	Type	Method	Validation
1	How is PM currently applied?	Analytic	- Observations, - Shell Web and GSAP research - Interviews with standard questionnaire. - Step by step method from literature.	Overview of participants. Results in a process work flow that describes the current situation.
2	What problems/bottlenecks do occur in the current process?	Empiric	- Observations - Interviews, - Meetings - KPI Dashboard	This results in a report that clearly provides the bottlenecks and the problems in the current situation.
3	How should the new end-to-end process look like to close the PM process loop?	Analytic	- Interviews - Brainstorm sessions and workshops, - Step by step method from literature.	A report on improvements by comparing the current situation to the desired situation.
4	What quick wins can be extracted from the new process?	Empiric	- Workshop - Group discussion	A list of quick wins that will be implemented.
5	How can the quick wins be implemented for assessment?	Analytic	- Discussion with in-company Supervisor - Getting a fixed contact person on the production unit that will be used for the pilot.	An implementation plan to first prepare and secondly apply the changes to be made.
6	What are the results of the quick wins implementation?	Empiric	- Using three colors to indicate successful implementation - Display all process steps. - Add remarks to every step.	An implementation report.
7	What strategic goal for PM should Shell Pernis set?	Analytic	- Literature to determine strategy structure. - Interviews - Quantitative analysis on expenses	- Strategic goal - Determination of performance gap - A mission to accomplish the goal
8	What resources are required to achieve the strategic goal?	Empiric	- Interviews - Quantitative analysis on KPI dashboard.	- A list of resources to be acquired.

Table 1. Research method

1.4 Aim and objective

The aim of this research is to create an efficient and effective closed-loop PM process for Shell Pernis to gain more benefits from the application of PM. The closed-loop means that output is connected to input to make it a continuously improving process. In terms of strategy this research aims at two different aspects. Firstly, continuous improving the new process and control the performance level of appliance. Secondly, future developments of this process containing predetermined innovations. Both aspects provide a set of goals that form the strategy basis.

This research's goal is to obtain knowledge that gives insight in the creation, planning, preparation and execution of PM plans. This knowledge contributes to a standardized PM process that enables Shell Pernis to further develop PM as it is equally applied on all production units. This research will provide a suggested process design which will be assessed and tested by implementation on one production unit. When this process is clear and tested a strategy can be made for PM at Shell Pernis. By setting out a strategic goal and mission to this strategic goal Shell Pernis will be able to develop PM. These two deliverables will contribute to solve Shell Pernis' problems.

1.5 Approach

As the research approach an observational point of view is adopted. This entails that the current process (As-Is)will be identified and charted by conducting interviews, observations and seeking for evidence in SAP, Primavera or other programs/documentations. Besides interviews and observations, several theoretical documents will be counselled. Since PM is not standardized on all production units within Shell Pernis, several deviating As-Is processes will be revealed. Subsequently a To-Be process will be designed by common means as applied by defining the As-Is process. Out of the improvements implemented in the To-Be process several quick wins to be assessed on credibility and effectivity in a pilot are extracted. This pilot, founded on an implementation plan, will be done at one or two production units which will be determined on a proceeded moment. This pilot will be controlled and real time results will be displayed to ensure the possibility to make the right conclusion out of an analysis on what the quick wins has delivered.
Remaining is the strategy that has to be written. The pilot results will serve as a significant input for this strategy, mainly on time planning for strategic goals. However, a second input based on innovational theories and ideas forms the basis to the formulation of the strategic goals.

1.6 Scope

Determining a clear scope helps a lot in effective project delivery. If no research boundaries are set correctly, wrong measurements will be made or the so-called *scope creep* might occur. The last one is explained as not knowing what is involved and what is relevant to the research and what is clearly not. The consequence of not having a proper scope is that the research could become a never ending story or a too large scaled project where an overview is likely to get lost. Unfinished or half work could be the result.

The main subject of this project is PM. Therefore, only the PM process at Shell Pernis will be involved. Before getting into the contents of PM a broader view on maintenance itself and how it is designed at Shell Global. Shell has internally developed a standardized asset management program called Global Asset Management Excellence (GAME). The contents of GAME can be found in Appendix 2. GAME was invented for multiple purposes. It was mainly invented to create uniformity in all Shell locations worldwide and to function as a tool to create optimal operational availability. GAME also created a new function within the Shell Downstream namely a coordinating role between operations and maintenance to optimize cooperation between those disciplines: Operations Maintenance Coordinator (OMC).

The most relevant process for this research is the Maintenance Execution (ME) of the GAME program. **GAME-ME** includes both CM and PM. However, the focus will be on the preventive part during this research. Indirectly, several other processes will be involved. The IPF, RCM and EI processes are the direct input for PM where also the OTM and AIM processes contribute to PM. IPF, RCM and EI are hereafter jointly indicated as *studies*. In terms of contents the PM process can be divided into several steps which will be visualized in the following graph where the GAME-ME process is the scope for this research and the dotted line indicates indirectly involved items.

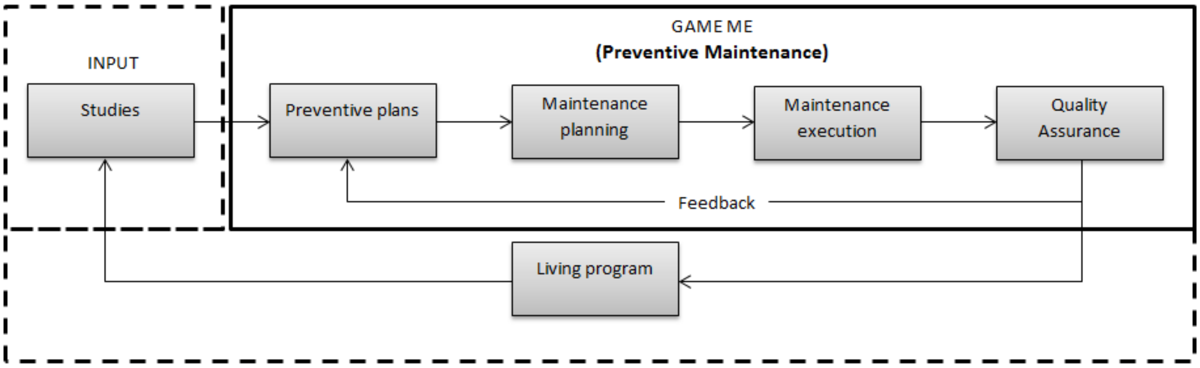

Figure 2. Research scope

Next to the studies the Living program is also related to the PM process. The Living program is no GAME process but rather a connection between two processes. When during the execution of maintenance somehow preventive plans do not seem to be correct it can be adjusted, removed or a new plan can be requested by the Living program. In that way, via a new study, preventive plans can be cleaned up.

Clearly this project will only concentrate on the GAME-ME PM process to optimize effectiveness in executing the preventive plans created by using received input from the studies. Cases where both preventive and corrective maintenance processes are involved are excluded from the project scope and not taken into account during this research.

1.7 Stakeholders

Either directly or indirectly the majority of Shell Pernis is somehow involved with maintenance, and so PM. However, this project focuses on the process of maintenance and so the stakeholders are only the ones directly related.

To start off the client for this research, the Maintenance Excellence Supervisor, is the most important stakeholder. Having the support and approval of this stakeholder in all steps and choices made during the project is highly important. Secondly the facilitator of the covering project, where this research is part of, is the next important stakeholder. This stakeholder will mainly serve in a supporting and consulting role. Every considerations or options throughout the project can be discussed with this stakeholder in order to gain guidance.

Last but not least are all the persons involved in the PM process of Shell Pernis. These stakeholders are really from all layers of the process from reliability engineers to craftsmen. As one could imagine, some are more significant than others. The PPs (PPs) will definitely be the most important stakeholders within this process since they fulfill a significant role in the process. It will be important to have close contact with them with a lot of communication. Sharing ideas, potential changes, and improvements in an early stage with the members of the process is something that has to be done in order to manage alignment of all stakeholders.

Since lots of people are involved and so multiple different opinions and interests will appear the main perspective and approach will always be stated again and again. The approach is to improve together the effectiveness of the PM process.

2 Background of the research

Before getting into the content of the research a brief introduction to the company and the main subject, being PM, will be given. This will be done to inform the reader with background information with the purpose to increase understanding about the research itself.

2.1 Research motives

PM is a maintenance policy to avoid unplanned downtime of assets and so optimize asset availability. This especially counts for a big complex refinery where enormous volumes of throughput are processed inside and between the plants. By failing non-compliance of planned PM tasks, determined by reliability studies, Shell could suffer both huge economical and HSE consequences. Therefore, Shell Pernis has a great preference for a well-structured, organized and standardized PM process which is currently missing.

2.2 Shell Nederland Raffinaderij B.V.

All around the world the Royal Dutch Shell, hereafter called Shell, is known as one of the biggest companies in the oil and gas industry. Shell describes itself as an integrated energy company that aims to meet the world's growing demand for energy in ways that are economically, environmentally and socially responsible. (Shell - What we do, 2016)

Shell is divided into five businesses and one of them is the downstream business. One of the companies within the downstream business is Shell Nederland Raffinaderij B.V., located in Pernis-Rotterdam, and is hereafter called Shell Pernis. Shell Pernis is the biggest refinery in Europe and is a high-complex refinery. In approximately 60 different plants oil products and chemicals are manufactured out of petroleum. This flexible refinery is able to process several different crude oils into its core products: gasoil/diesel, gasoline, kerosene, base oil (lubricants), LPG and fuel oil. Besides the refining plants Shell Pernis has some chemical plants. Those plants produce several chemicals such as polyols and solvents (e.g., acetone, alcohols and glycol ethers). When the refinery of Shell Pernis operates on full capacity it processes 20 million tons of crude oil per year which equates to the incredible amount of 750 liter oil per second. (Shell Pernis, 2015)

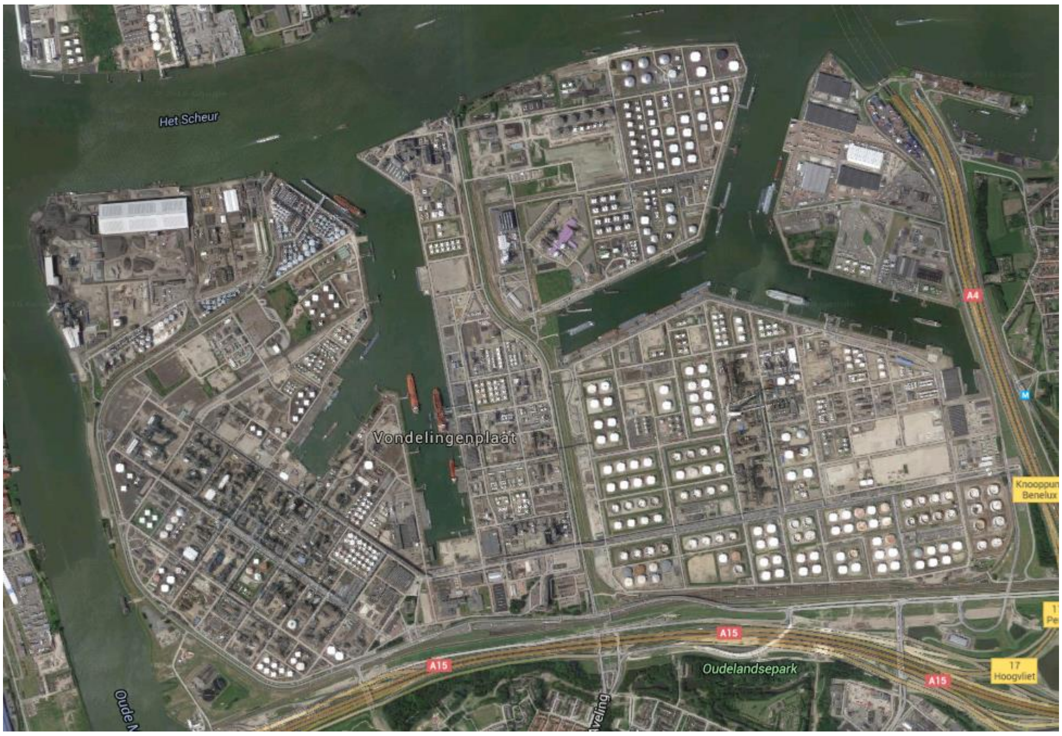

Figure 3. Shell Nederland Raffinaderij B.V., Pernis-Rotterdam (Google Maps, 2016)

2.3 Introduction to preventive maintenance

To enable Shell Pernis to process 750 liter of crude oil per second available assets are of crucial importance. Therefore, failure prevention is required and in order to do so the performance of maintenance is essential. With a throughput like Shell Pernis the level of asset availability is related to huge financial consequences.
Within the world of maintenance several policies are in existence and all of them can be divided into two kinds of maintenance: corrective and preventive. Since corrective maintenance such as replacements and repairs of assets, equipment parts or components is often highly expensive PM is preferred by many asset owners. Besides, PM, if applied correctly, prevents downtime of assets and so the costs that are suffered due to unplanned asset downtime.

PM is a very important ongoing accident prevention activity, which you should integrate into your operations/product manufacturing process. (IAPA, 2007)

Reliability of assets is one of the main subjects in terms of PM. Examining an asset's future reliability by predictive modelling can provide a lot of information about potential failures and so potential unplanned downtime of an asset. The ultimate goal of maintenance is to keep an asset's performance level above the level of failure. Where corrective maintenance is the activity of lifting the performance level from beneath the failure level to a desired performance level above the failure level; PM is to perform preventive actions just before an asset's function is about to fail. As one can see in the schematic representation below, the P,F-interval is the time between a potential failure and the moment in time a failure is going to occur. It is the challenging practice to perform PM as close to the functional failure as possible since that will result in a maximum PM interval without having ever an occurrence of functional failure.

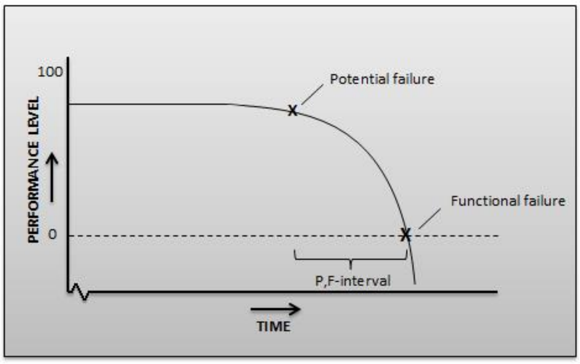

Figure 4. Potential and Functional failure

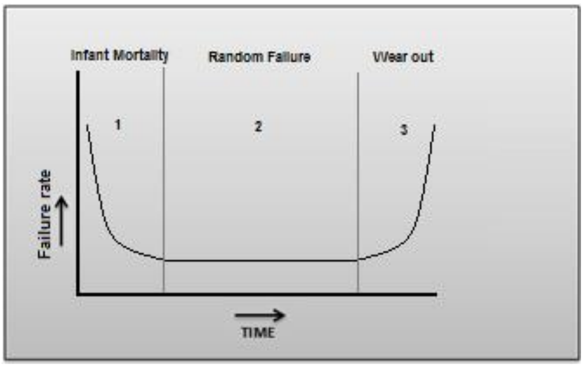

Figure 5. Bathtub curve

The background studies on reliability and how to define the right PM intervals are addressed more detailed in the theoretical framework (Chapter 3) where, among others, the contents of PM are furtherly described. PM is applied while the asset is still in operation or during planned downtime. However, PM is often considered as complex and unclear. When PM is not applied correctly it is very likely to result in corrective work with all costs attached. Therefore effective PM is significant for every asset owning company, including Shell Pernis.

In figure 5 the bathtub curve is shown. This curve represents the failure rate against operational time of an asset. The curve exists of three periods; the first is the start and the failure rate is reduces exponentially because of infant mortality. The second is normally the largest and represents the middle period where the failure rate is flat and random. PM is specifically applied in the third period as the failure rate shows an exponential growth due to wear out of the equipment. In other words, PM is used to prevent the growing failure rate getting to high because of measurable damage and potential failures.

3 Theoretical framework

PM is, certainly for Shell Pernis, a key activity in terms of financial interests which makes effective application highly beneficial. Along this theoretical framework involved theories and literatures are being explained, reviewed and surveyed. The theoretical framework contributes to the knowledge and methodologies that is required to answer the research question:

What end-to-end process does Shell Pernis need towards an improved Preventive Maintenance strategy?

3.1 PM strategies

In this section a survey is done on ideas and philosophies on a business strategies regarding PM. Since one of the key deliverables of this research is a strategy on PM for Shell Pernis, it seems to be necessary to find out what requirements an adequate strategy has.

3.1.1 What is a strategy?

Firstly, it is important to understand what a strategy is and therefore a brief explanation about the phenomenon is required. A strategy is not a goal or mission as many people believe but it is rather a plan that enables a company to achieve accomplishment of the company's mission. Therefore, the main requirement of a good strategy is a clear definition of what is going to be achieved. In other words, the goal of a company should be set. Besides this, it is necessary for a company to adopt an organizational mindset that results in a strategy that is implemented, managed and monitored the same as any other business process. (Jonas, 2000)
Within any organization there are different business levels. Logically, this is not different in a maintenance organization. The three business levels in maintenance management are:

Figure 6. Business pyramid

To understand what a strategy does and what it contains an overview of the three levels is given.

Strategic: Addresses long term maintenance priorities. It has to fill current or potential gaps between current and desired equipment/asset performances. In order to fill the gaps a maintenance plan is obtained at this level. The plan contains critical targets, such as critical equipment for a refinery as Shell Pernis, and it contains the question: "**When are we doing plan A what to achieve X?**"

Tactical: Determine the correct assignment of maintenance resources to fulfill the maintenance plan set in the strategic level. Specific tasks on short term are organized in order to achieve the goal set by obeying the maintenance plan. The main question says: "**What do we have to do to fulfill plan A?**"

Operational: Ensures that maintenance tasks are carried out by skilled technicians, in time scheduled, following the correct procedures and using the right tools. This is the area where actual maintenance is performed. Ultimately, the operational part of the organization provides the data and information to both tactical and strategic level to set new goals, plans and tasks on both short and long term. The typical question for operational levels is: “**How are we going to do task Y to fulfill plan A?**”
(Rastegari, 2010)

What can be concluded is that a strategy is the most influencing and important part of the organization since all remaining activities are either directly or indirectly depended on what is decided in the formulation of a business strategy.

3.1.2 Requirements for setting a strategy

PM is often considered as a complex and difficult practice. The importance of a maintenance strategy is set forth by the industrial management department of the University of Seville. They explain that a strategy conditions the success of maintenance in an organization, and determines the effectiveness of the subsequent implementation of the maintenance plans, schedules, controls and improvements. Effectiveness shows how well a department or function meets its goals or company needs, and is often discussed in terms of the quality of the service provided, viewed from the customer’s perspective. This allows the research to arrive at a position to be able to minimize the maintenance indirect costs, those costs associated with production losses, and ultimately, with customer dissatisfaction. (University of Seville, 2009)

However, it’s more important to know what requirements are attached to setting a PM strategy. According to A.C. Márquez (Márquez, 2007) a few steps are pointed out as necessary in order to set a proper maintenance strategy:

- Deriving from corporate goals the policies and objectives for maintenance. These objectives may include: equipment availability, reliability, safety, risk, maintenance budget, etc., and should be communicated to all personnel involved in maintenance, including external parties;
- Determination of current factory/facilities performance;
- Determination of the target performance measures (KPIs). Improvements will be made based on accepted business, user and maintenance management performance indicators;
- Establishing principles to guide strategy implementation by means of planning, execution, assessment, analysis and improvement of maintenance.
  (Márquez, 2007)

The requirements are visually shown in the maintenance strategy model (Márquez, 2007) in the appendices (Appendix 3)

3.2 End-to-end Process

An end-to-end process is more than just a process that flows through an organization from one end to another. The end-to-end process is often called a cross-functional process which means that multiple disciplines are involved with overlap on some areas throughout the end-to-end process to achieve a common goal. Also known as a Matrix Organization (Saylor Academy, 2012)since multiple employees of different departments commonly work on a project, product or assignment. This looks as follows:

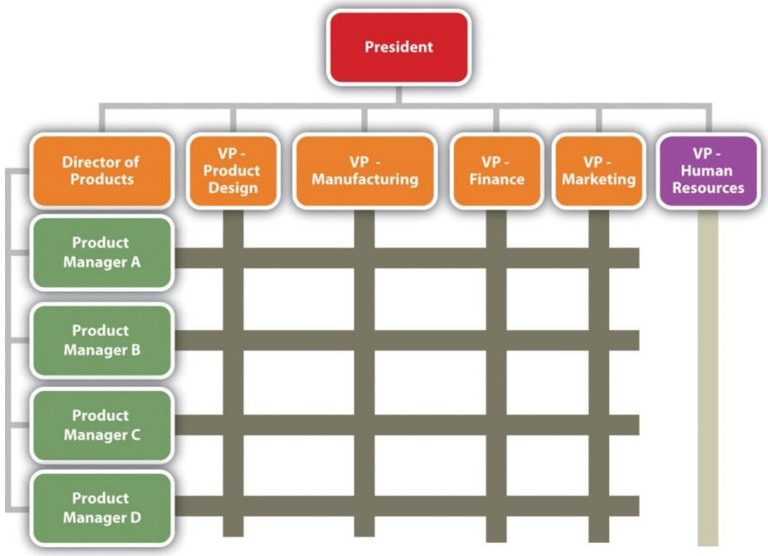

Figure 7. Example of a Matrix Organization

An end-to-end can be described as a process that comprises all of the work that should be done to achieve the process goal. Therefore, end-to-end means "from the very beginning to the very end and back". (Belaychuk, 2015).

Since the activity of maintenance is done for the asset owner as a certain service the asset owner is often compared or seen as a customer. Therefore, the end-to-end process of PM can be described as follows as well: Typically, an end-to-end process is a chain of process steps (or sub-processes) that starts as the result of a customer trigger and proceeds through until a successful outcome for the customer is achieved. (Davis, 2010) A very interesting thing about key characteristics of an end-to-end process is written by R. Davis in his column on the website of BP-Trends (see Bibliography for URL) is his involvement of the customer, so for PM the asset owner/user and Reliability Engineer. The key characteristics according to Davis (Davis, 2010) are:

- It must reflect the customer's view of when they initiate the process and when they get a successful outcome.
- It must reflect the organization's view of when the customer interaction is complete and a business objective has been met.
- It must be capable of being measured, and those measures must take account of the customer view and the organizational view.

What really takes the interest is on the moment one substitutes the word customer by asset owner/user or, in this research's case Production Unit Manager, a whole new mindset appears. Suddenly, the entire process has to be based on what Shell Pernis initially wants to achieve: maximal production by maximal availability of their plants. Since the core mission for maintenance is to ensure that physical assets continue to do what their users want them to do (Moubray, 1997) an end-to-end process has to be designed to those requirements.

The 'end-to-end' part of this subject is to be clarified easily. It means that one end of the process (the start) is connected to the other end of the process (the end) are connected to each other which results in a closed-loop. In this way the process is in fact a never ending process and continuously improving the PM activities.

3.3 As-Is process vs. To-Be process

A process can always be improved and developed in terms of effectiveness and efficiency. Whenever someone wants to improve a process to approach optimality, it has to determine two versions of that specific process; an As-Is process, which indicates how the process currently is applied and looks like. Secondly, a To-Be process where eventual improvements are implemented and a higher performance level on effectiveness are achieved. In other words the To-Be process is the improved version of the As-Is process.

Within this research those kinds of processes are consulted. However, how are those processes correctly created? Alec Sharp and Patrick McDermott's (Sharp & McDermott, 2009) publication *Workflow Modeling* states on building an As-Is process: "It is not as simple as just grabbing a pen and starting a diagram." (Sharp & McDermott, 2009) Building an As-Is process is explained as going along five important steps which will be explained more in detail in the next section.

3.3.1 Understanding an AS-IS process

The five steps that supports to build and understand the As-Is process of an organization are one by one explained according to Alec Sharp and Patrick McDermott (Sharp & McDermott, 2009). These are exploited in Appendix 4.

3.3.2 Designing a TO-BE process

Designing a TO-BE process has several purposes. The first and most common one is to improve organizational performances by adjusting the AS-IS process to the TO-BE process. Secondly, it produces a description of the important characteristics of the TO-BE process and it identifies the specifications for the new process.
The same reference is used on explaining how to get from AS-IS to TO-BE in a few steps to be taken according to Alec Sharp and Patrick McDermott (Sharp & McDermott, 2009). Similar to the previous section this list is exploited in Appendix 5.

3.4 Contents of PM at Shell Pernis

Before getting into the research itself it is very important to review the main subject's (PM) contents. What PM exactly is can be found in the first chapter of this document (see section 1.1.2). Since this is a very broad concept where can be endlessly written about the focus will be on the parts which are applied and integrated at Shell Pernis. Shell Pernis has divided their current PM into three parts: Reliability-Centered Maintenance (RCM), Instrumental Protective Functions (IPF) and Risk Based Inspections (RBI). However, some more contents of PM are surveyed in this section.

3.4.1 Reliability-Centered Maintenance

Reliability-Centered Maintenance (RCM) is one of the key contents of PM. To determine a maintenance policy for one specific asset the principle of RCM prescribes seven main questions to step through. Those seven questions have to be answered carefully in order to create the optimal maintenance policy for that specific asset. Since every answer affects the outcome severely the RCM study is recommended to be performed by a team rather than one individual.

The most famous literature about the principles of RCM is the book written by John Moubray (Moubray, 1997). In his book he describes the theory from the front to the back starting with the first question and proceeding to the seventh with additional chapters on how to implement and control the RCM process. The seven questions for an asset owner to go along to are:

1. What are the functions and associated performance standards of the asset in its present operating context?
2. In what ways does it fail to fulfil its functions?
3. What causes each functional failure?

4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What can be done to predict or prevent each failure?
7. What should be done if a suitable proactive task cannot be found?

(Moubray, 1997)

According to a well-known RCM guide of NASA the main goal of RCM is to place great emphasis on improving equipment reliability through the feedback of maintenance experience and equipment condition data to facility planners, designers, maintenance managers, craftsmen, and manufacturers. This information is instrumental for continually upgrading the equipment specifications for increased reliability. The increased reliability that comes from RCM leads to fewer equipment failures, greater availability for mission support, and lower maintenance costs. (Kidd, 2008)

3.4.2 Instrumented Protective Functions

Instrumented Protective Functions (IPF) is a type of PM which is oriented on instrumental equipment only. Examples of instrumental equipment are flow level measuring instruments, pressure level instruments, temperature level instruments etcetera. IPF is a control system utilized to automatically activate a control function to protect against an undesirable occurrence in an operating unit / facility. IPF are designed and regularly tested to ensure high reliability.

On the online Shell Wiki Instrumented Protective Function (ShellWiki, 2012), URL in the References, is defined as "a function comprising one or more initiators, a logic solver and one or more final elements whose purpose is to prevent and mitigate hazardous situations". In lay man terms, this is a set of instruments used to measure a process condition in order to detect when a pre-identified hazard is about to occur (initiator), use the results of the measurement to determine if the hazardous situation is about to happen and decide what needs to be done to prevent it, and send a signal to the act to the device which can take the corrective action required (logic solver), the device which can take corrective actions received this signal and acts in a predetermine way and time to bring the process to a safe state (final element). An example of this is when you are driving, and your eyes (initiator) see a dangerous situation about to occur, this is reviewed and interpreted in your brain (logic solver) which then decides what needs to be done by your body (final element) this can be to press the brakes, turn the steering wheel, honk the horn or scream. As can be imagined, checking that is works effectively is an essential part of asset integrity.
A more fundamental analysis of instrumented protective functions (IPF) can be obtained by a formal IPF analysis as described a Design and Engineering Practice (DEP) study. DEP is a Shell developed engineering and design standard and guide.
This analysis optimizes the design of the IPF from a consideration of:

- Frequency of demand
- Potential extent of injury, environmental impact, asset damage and production loss
- Duration of presence of personnel in the danger zone
- Possibility to avert the hazard

(ShellWiki, 2012)

3.4.3 Risk Based Inspections

Risk Based Inspections is one of the most known preventive activities in the maintenance branch. RBI is a combination of technologies providing industries with a risk based method for evaluating and developing inspection plans. RBI works by calculating both the consequences of possible failures and the likelihood of those failures. The combination of consequences and likelihood identifies which equipment warrants the most attention for managing risk. (Kallen, 2002)

Interesting to know is what the required and expected key outcome of any RBI is. Craig Emslie and Karen Gibson (Emslie & Gibson, 2010) provide this key outcome in a technical article as follows: A

prioritized and focused inspection schedule. This ensures high-risk items get correct scrutiny and produces a safety-focused and cost-effective inspection scheme. RBI is now recognized as a key tool in meeting legislative requirements, as detailed in the HSE's best practice guidelines.
There are many RBI schemes in use, but they have a number of common elements:

- Assessment of the credible threats to an item of equipment
- Potential failure modes and mitigation measures
- Resulting consequences
- Associating a measure of risk with each item
- Combining risk with inspection history to determine future inspection (Emslie & Gibson, 2010)

However, often the schedule of inspections is partly defined by law and regulations by the government. Especially on a complex refinery such as the refinery of Shell Pernis where plenty of dangerous processes, and so HSE-critical equipment, are operational it is obviously that this law and regulations have great impact on the inspection interval. Logically, the law and regulations overrule any kind of reliability optimal inspection intervals.

3.4.4 Condition Based Maintenance

Predictive maintenance can be applied in several ways. One of them is condition based maintenance (CBM). This has to do with cost optimization which contains a well-educated estimation on maintenance and operational costs. As one could understand, CBM will be considered and approached a preventive policy since this research majorly concerns applying and improving PM.

CBM is a maintenance philosophy used by industry to actively manage the health condition of assets in order to perform maintenance only when it is needed and at the most opportune times. Since Shell is economically very sensitive for asset downtime it has a high priority of preventing this from occurrence. However, in an optimal situation PM is applied just before a failure is going to occur. To achieve or approach this, CBM can offer possibilities to do so. Besides, CBM can drastically reduce operating costs and increase the safety of assets requiring maintenance. (Zubik, 2010)

The main function of CBM is to identify potential failures by monitoring asset health by e.g. vibration measurements and lubricant analysis to consider a point of interference to prevent a failure from occurrence. When describing the key features of CBM it comes down to several aspects but he most important and relevant features are health monitoring and potential failure identification.

3.4.5 Key Performance Indicators

Whenever a business tries to improve or wants to measure developments within the organization it has to control their performances. The most important aspect of performances is to visualize all relevant levels of whatever discipline is involved. KPIs are measures that a sector or organization uses to define success and track progress in meeting its strategic goals. (Rozner, 2013) For Shell Pernis possible significant KPIs could be the amount of overdue maintenance work orders, the backlog for every part in the process to define bottlenecks, amount of preventive and corrective work orders and so on. To gain even more information an organization could measure and monitor several KPIs even more specific e.g. on different time intervals, moments of the year or per PU. For example, one could compare the amount of overdue work orders of PU X from the first week of December with the second week of that month. In this way endless combinations can be made to see where bottlenecks and/or possible improvements are.

Another benefit of maintaining and recording the right KPIs is to identify possible trends. Whenever a certain trend seem to appear responsible individuals could track potential problems before any adverse happens. This is made easier when applying a KPI Dashboard. In such a dashboard all relevant KPIs are monitored and closely being watched. Another advantage of a dashboard is that certain supportive visualization with e.g. colors can be used to put the focus on urgent matters.

3.5 PM innovation

What PM can deliver to any industrial business is impressive if applied correctly. Therefore Ricky Smith has on behalf of GP Allied designed a matrix where any company can assess their *maturity* in terms of PM (Smith, 2012). This program is often used to determine long term, strategic, goals to develop the PM process, facilities, expertise, resources and more to an advanced level. In the appendices of this research report the matrix is shown which contains of four sections;

1. PM maturity elements
2. Supporting workflow elements
3. PM procedures
4. Results/Scorecards

These four elements provide five levels of performance of PM. Assume a company or organization has managed to achieve the level 5 of all components divided into the four sections. According to Ricky Smith's Maturity Matrix (Smith, 2012) a company or organizations is in that case considered fully mature in terms of PM.

4 Current PM Process

Since this research's approach starts off with the description of the current situation of PM. However, before going in depth to this process an overview on the organizational structure of maintenance within Shell Pernis and the application of maintenance is provided as background information.

4.1 Maintenance at Shell Pernis

As written previously the following section serves as background information which makes it easier and clear to understand subsequent sections. In the structural overview of the maintenance organization of Shell Pernis all departments are shown and briefly introduced to gain basic knowledge how the organization works. Afterwards, the processes in which maintenance is applied will be discussed.

4.1.1 Maintenance organization

The maintenance organization at Shell Pernis is divided into several parts. Shell Pernis has one maintenance manager who is ultimately responsible for the condition and availability of all plants within the refinery borders with all related costs, performances and risks attached. Further on, the maintenance organization of Shell Pernis exists of five different divisions: Decentralized, Centralized and Supportive.

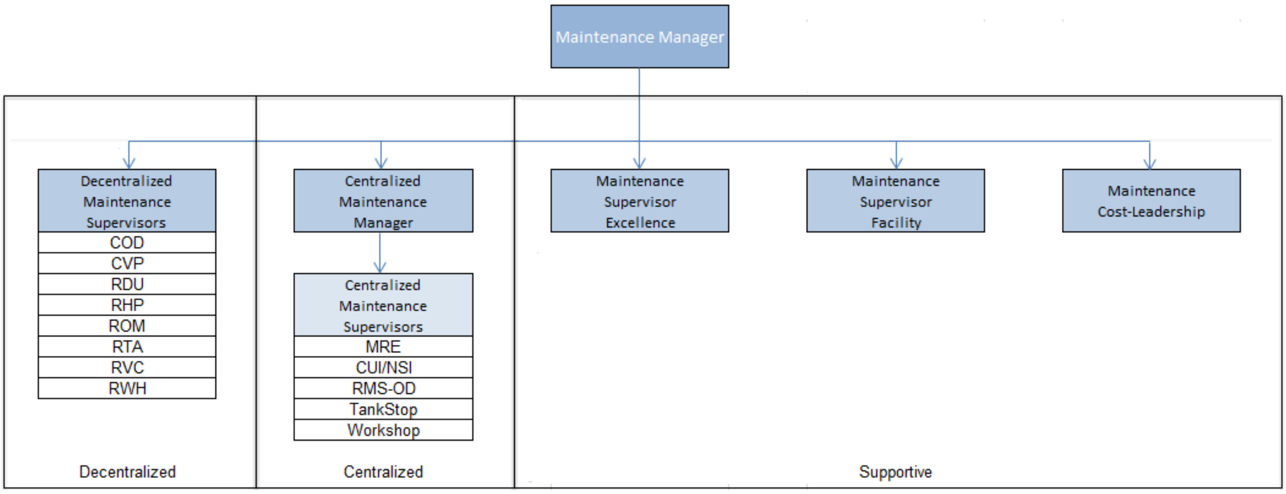

Figure 8. Maintenance organizational structure

Decentralized

As shown above the decentralized maintenance entails eight departments fairly divided over the PUs, which are mentioned as abbreviations in the overview in figure 8. All eight departments are spread over the refinery area. Appendix 1 provides a plot plan of the Shell Pernis site to give an idea of geographical size.

Centralized

Next to the decentralized departments five centralized departments managed by one centralized maintenance manager exist. Those five departments lead by one maintenance supervisor are:

MRE: Major Rotating Equipment; Take care of e.g. big pumps which are maintained by a group of highly skilled specialists.

CUI/NSI: Corrosion Under Isolation/Not Stop-related Inspection; A group of mechanics repair equipment suffering external corrosion found by removal of isolation during inspections which are performed when the plant is in operation.

RMS-OD: Electricity generating and distribution to serve as power source provider for all plants on the Shell Pernis site.

Tankstop: Lots of tanks are located to provide storage capacities for temporary storage of any product which need to be buffered. A team of tank cleaning and repairing specialists take care of periodical stops to warrant the integrity of the tanks.

Workshop: The workshop forms a group of mechanics multidisciplinary specialized to perform repairs on equipment for all maintenance departments which cannot do the repair job on location at the plants.

Supportive

The remaining departments of the maintenance organization are three supportive departments which serve as a resource or contribute to optimization of the decentralized and centralized departments.

Excellence: A department that tries to continuously improve the maintenance performances by doing research on how to increase maintenance performance levels. This research on PM is therefore initiated by the Excellence department.

Facility: Provides the executive departments with all required maintenance facilities to ensure maintenance can be performed adequately.

Cost-Leaders: The department that economically controls the refinery's maintenance.

4.1.2 GAME Maintenance Execution

Shortly introduced previously in the first chapter of this research report is the Global Asset Management Excellence (GAME). This program is functioning as a guide about how to apply asset management and what elements it contains to professionally conduct it. One of these elements, and for this research the most relevant, is the Maintenance Execution process. This process is charted and shown below as it is desired how to be applied. As can be seen it is divided into a preventive and corrective loop. The focus in concentrated on the upper loop being the PM process as how it should be performed.

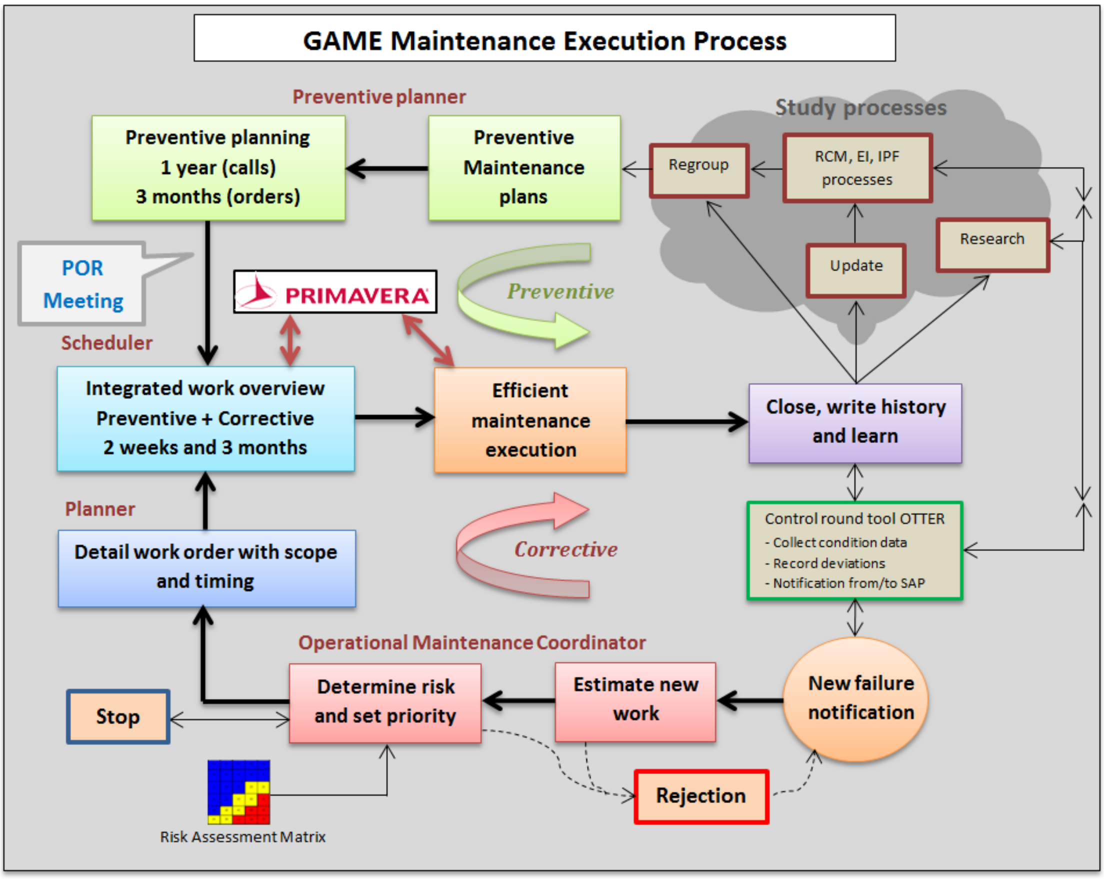

Figure 9. GAME Maintenance Execution process

PM departs from initiative output of other elements of the GAME program. These are the RCM, EI and IPF elements which unitedly form the study processes, shown in the right top corner of figure 9. Once study results are known a maintenance plan is made in SAP. Three months before the BFD a work order is created automatically by a preventive plan. During a POR meeting the list with newly created work orders is discussed to get all stakeholders informed about contents of the planning for the following weeks. Subsequently an integrated work overview is made by the scheduler. This overview is stored in Primavera, a Project Management software, where all workload can be scheduled over the involved mechanics, operators, contractors or facilities. The involved executors will find an individual planning which they can anticipate upon which leads to efficient maintenance execution. To close the loop history has to be written where indirectly the studies should respond to in order to learn from the past and improve the PM for the future. This history either exists of preventive and corrective maintenance data.

Alongside Primavera there is another software globally integrated by Shell which is, as mentioned in previous occasions, SAP. SAP is an ERP (Enterprise Resource Planning) software that has been used by Shell for multiple purposes. For the maintenance departments of Shell Pernis SAP is used as a tool throughout the entire maintenance process. For corrective work it goes from new failure notifications to work order creation, planning, approval, execution and closure and finally closure of the notification and the history stored in the software. The statuses that SAP sets for corrective notifications and work orders are shown in the graph below.

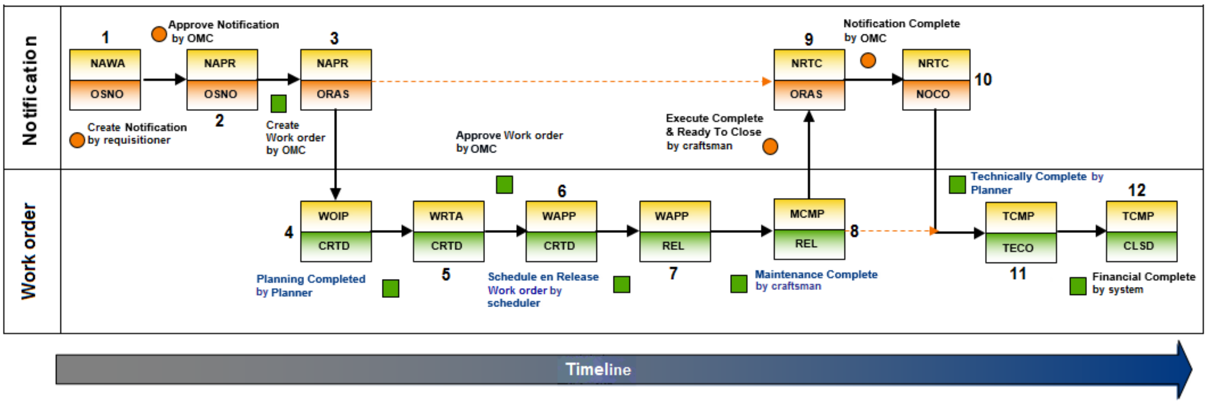

Figure 10. GAME ME process with SAP statuses for corrective maintenance

Unfortunately and surprisingly such a schematic flowchart for PM workflows with attached SAP notification and work order statuses does not exist. However, those statuses do exist at least for the work order flow since PM does not generate notifications because the work orders are created automatically according to preventive plans. The next section goes deeper into this specific topic of how this process is decorated together with research on compliance of the PM loop in the GAME ME process. This section is simultaneously the most important part of this research.

4.2 Defining current situation

This section provides the PM process as it is currently applied. For this entire section counts that it is only a brief explanation and overview for the simple reason that further elaborated As-Is process can be found in the appendices where a report on improvement is stored. In this report one could read what the current situation is. However, in the following paragraphs can be read which main findings where done in the execution phase of this research for defining the current situation; called the As-Is process.

4.2.1 As-Is PM process

The first sub question of this research is faced in this section which will try to provide an answer to it. As mentioned in the first paragraph of section 4.2 the elaborated processes are to be found in the appendices. Therefore the key aspects of the process are summarized and established as the answer is formulated for the question:

How is PM currently applied?

The PM process as it is currently applied will be called the As-Is process from this point. As explained in the theory of Sharp and McDermott (Sharp & McDermott, 2009) the practice of defining the As-Is process starts with setting a team. To define the team a table is made where all departments were set against the participants of the process. Based upon presence, availability and recommendations the participants are chosen. As shown in the table below the cells marked green were the persons selected to be involved in the interviews and discussions.

	MS	aMS	MTL	Sen.Pl.	Prev.Pl.	Planner	(a)OMC	Job Ld.	Sched.	ME	RCM FP	IPF FP	RBI FP	IT Dev.
RTA														
RVC														
RWH														
RHP														
ROM														
RDU														
CVP														
COD														
RMS-OD														
PER														

Table 2. Overview of participants

The next step as described in *Understanding the As-Is process* (Appendix 4) is to organize and initiate the modelling sessions. In these sessions with the participants, marked green in the table above, simple questions are asked to find out what the main steps in the process are. By proceeding to follow the steps defined by Sharp and McDermott (Sharp & McDermott, 2009) several more methods are used besides interviews with stakeholders involved in the process either directly and indirectly. These methods are extracting logics from the BBS procedures and the GAME ME descriptions like for example the process diagram in section 4.1 (Figure 9). Next to this, experience from previous project and employment as planner at Shell Pernis has also provided a lot of knowledge. The result of this phase of the research is a Level 1 process flow:

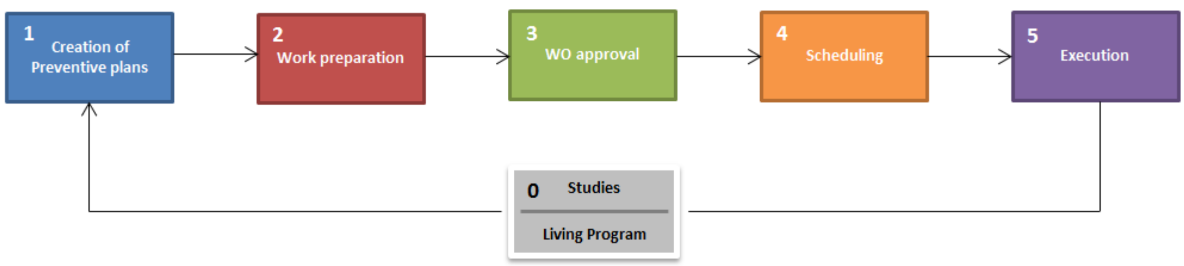

Figure 11. As-Is process Level 1

0. Studies / Living Program

The first process starts as new studies are performed and the results are forwarded to the PP. The studies are done in the so-called Living Program which covers several GAME items related to studies.

1. Creation of Preventive plans

A new preventive plan is created and filled with information received from the process input; the Living Program. A preventive plan contains of one or more *items* and every item contains one task list. This task list states what activities have to be done on what interval. The plan is further completed by adding scheduling parameters.

2. Work order preparation

A preventive plan based upon the scheduling parameters generates work orders in SAP. These work orders need preparation before they are available to execute. In the preparation phase the field scope is set, the requisitions for materials and contractor services are made, costs estimation is done and required documents are made and saved as attachments.

3. Work order approval

As the work orders are prepared completely they have to be approved by the assistant Operations Maintenance Coordinator (aOMC). The work orders are approved upon correctness of the task lists and cost estimations.

4. Scheduling

All task lists from the work order are scheduled by the Scheduler of a department. The ERP Primavera is used as a scheduling tool. In Primavera all maintenance activities of Shell Pernis can be found.

5. Maintenance execution

According to the schedule the maintenance tasks are executed. All maintenance activities are guided by the Job Leader. The Job Leader checks afterwards if all tasks are done properly and then sets the work order as complete. The Sr. Planner of a department will afterwards close the work order financially if any costs were involved.

The Level 1 process flow was now set and this was checked by the supervisor. During the interviews in the first month of the project frequent contact was maintained to make sure the right track was still followed. According to the steps for understanding an As-Is process from Sharp and McDermott (Sharp & McDermott, 2009) subsequently a Level 2 process needs to be created. This will be done by asking the participants the same set of questions. These questions can be found with explanation in the third step of fourth appendix of this report. The questions are:

- What makes it go?
- Is anyone else involved?
- Does the name of the step accurately convey the result?
- Are all outcomes shown?
- How does it get there?

Since these questions are asked a new process was created. It contained all steps in more detail, several more work order routes and it shows the responsible and supportive stakeholders. As one could imagine, the process was not directly complete and accurate. The Level 2 process was changed and adjusted several times because of small mistakes, misinterpretations, too many or too few details. It took some more interviews, meetings and research to ultimately end up with the final Level 3 As-Is process of PM at Shell Pernis.

However, the final As-Is process with attached descriptions of every step was also a deliverable for the client. It is therefore set in a separate report together with the improvements and the final To-Be process. This report is called the Report of Improvements and can be found in the appendices. The first chapter defines the As-Is PM process and provides an answer to the first sub question of this research.

5 Improved PM process

Proceeding towards a new improved PM process requires to analyze the defined As-Is process. Out of this analysis problems and bottlenecks are extracted and explained in the section about main findings. To erase these problems and bottlenecks changes have to be made and implemented in order to improve the process. In other words; this chapter provides the answer on the question of how the new end-to-end process should look like. In addition the client had the desire to close the loop of the PM process.

5.1 Analysis of the As-Is process

This section of chapter 5 focuses on the As-Is process by analyzing it and extracting its weaknesses, problems and bottlenecks. The sub question to be answered states:

What problems/bottlenecks do occur in the current process?

Several problems and bottlenecks came to the surface during the analysis of the As-Is process defined in the previous chapter. Again these will explained in detail in the previously introduced Report of Improvements. However, in short this section provides the main problems that are currently present in the process. The main findings on this topic are the following problems and/or bottlenecks summarized:

1. No checkpoints or assurance

The GAME ME process for PM does only contain one major check and one small assurance step. In a business like Shell Pernis this is definitely too few. As explained in the theoretical framework one of the main aspects of a proper process is that it must reflect the customer's view when they initiate the process and when they get a successful outcome (Davis, 2010). For PM the initiator of the process is the Reliability Engineer. When reading Rob Davis' primary aspect of a successful process the outcome must be compliant to the initiative which requires interaction of the customer. This should be achieved by checkpoints throughout the process and interim assurance. However, the Reliability Engineer is completely out of sight and control after the results of his study are forwarded into the GAME ME process.

Next to that only one check is done by a participant of the PM process which is a small check on prepared work orders consisting of checking the task list and the cost estimations briefly.

2. No closed loop/feedback loops

According to Anatoly Belaychuck (Belaychuk, 2015) a process needs to be end-to-end. This means one end of the process must be linked to the other and back which makes it a closed loop. Despite the loop back to the Living Program, there is no feedback loop within the PM process itself.

A weakness of this process is therefore that the same mistakes might be made over and over again since there is no information flow back to earlier phases of the process. Not only mistakes will be made multiple times, resulting in CM effort or rework.

3. Repeatability

Since PM is a reoccurring matter and since no feedback loops and no complete preventive plans are present, a lot of repeatability is occurring in the process. As PM is a routine activity one plan, made by the PP, generates a work order every determined interval. This means if a plan is lacking of information, contains faults or else all generated work orders from this plan require corrective efforts. Those corrective actions are done by a Corrective Planner (CP) in the first phase of a work order (WOIP). However, in the execution phase also failures or incorrectness might be noticed. This could currently be feed back to the CP by means of a feedback field on the front sheet of a work map. Unfortunately, it turns out to be that this work map does often not return to the CP or PP and if so, it is not processed in the preventive plan.

4. No ownership
A somewhat more behavior issue that is found by observation in the As-Is process is a lack of ownership. Especially from the moment a preventive plan generates a work order. The work orders are distributed by the PP in the department. These work orders, if requiring preparation, are prepared by the CP. However, the CP sees the preventive work orders as possession of the PP, where the PP feels only responsible for the plans and not for the work orders. Obviously this does not improve the quality of the work orders in principle.
At two departments of Shell Pernis, the PP was permanently situated in the central office building. The other PPs are situated two days a week in the central office building and three days at the department. For the departments of this PP, RTA and RVC, there was barely any contact between the CP and the PP. This resulted in an even bigger lack of interest of the CP to feel owner over the preventive work orders.

5. No history and no evaluation
In the As-Is process of PM there is a lack of compliance to the set GAME ME process by Shell. As can be seen in Figure 9 the process as it should be applied states that after efficient maintenance execution history must be written and lessons must be fed back. For most of the PM work orders the system is technically incapable to write history since the work orders are MX01 types and do not generate notifications to write history.

6. Incorrect plans
Over the past few years a lot of PM plans are created by PPs. The problem is lately occurring that a lot of those plans appear to be incorrect, incomplete, inactive, double or whatever. In total Shell Pernis has over 30.000 preventive plans which all generate work orders on a certain interval. One of the main problems concluded from this analysis is that there is a huge lack of quality of these plans.

5.2 Suggested improvements

This section describes how the above stated problems can be erased and how the process can be improved. In short; what improvements should be implemented to move from the As-Is situation to the To-Be situation? Similarly as the previous parts these suggestions are described in more detail in the Report of Improvement to be found in the appendices.

5.3 To-Be PM process

After a lot of discussions, meetings and workshops the new PM process was created. This To-Be process is the As-Is process with added improvements. The sub question that will therefore be answered in this section is:

How should the new end-to-end process look like to close the PM process loop?

The new To-Be process is the key product of this research. In the Report of Improvement, which can be found in the appendix, a step by step explanation of the new end-to-end process is provided. The answer on the third sub-question of this research is therefore an overview of this process with all steps attached to it. In the work instruction that subsequently follows a more detailed explanation of every single step of the process is given.

The most important features of the new end-to-end process are:
1. LTLP tool; A new tool for requesting new preventive plans. (See **<??>** for the manual)
2. Assurance provided by the RE on the PM process.
3. Completion of task lists when making a new preventive plan in SAP.
4. Several control points throughout the PM process.
5. Feedback loops to improve preventive plan quality.
6. Writing history on MX02 orders.

6 Implementation

In this phase the new process in the To-Be situation is tested in order to assess the suggested improvements. The ROM is selected as pilot PU on recommendation of the in-company supervisor with several arguments. One of the arguments is that the assistant Maintenance Supervisor (aMS) is facilitator in the overall project where this research is part of. He is therefore known and very willing to cooperate with this project. Since he knows the members of the maintenance group of the ROM better than a researcher, this is a valuable thing.

6.1 Defining the quick wins

By implementing this new To-Be situation it's found out what value certain improvements have. In order to be able to do so the quick wins need to identified. Quick wins are improvements that can be implemented and measured in short terms. The quick wins can therefore be implemented during this project period, while the improvements not determined as quick wins will be left as recommendations.

What quick wins can be extracted from the new process?

By referring back to the suggested improvements stated in the previous chapter, an indication is needed whether the improvements are able to be implemented on this moment.
The ones that are defined as quick wins are explained below:

1. New program for requesting new plans, processing new plans and assurance of the RE on new plans. In addition this new program has to be tested.
2. Completion of the task lists when making a new plan instead of in the work preparation phase.
3. Saving operational documentation in AIM on FLOC.
4. Creating planning list for check and control by Sr. Planner.
5. Realization of the feedback loops for continuous improvement of plan quality.
6. Scheduling of all types of preventive orders (@, #, $) by Scheduler only.
7. Writing history on MX02 orders.
8. Agreement with REs to perform analysis on history.

6.2 Implementation plan

In this chapter the answers on three sub-questions are given. Those answers will show what the new process can deliver for Shell Pernis. The fifth sub-question therefore states:

How can the quick wins be implemented for assessment?

According to Deming's PDCA-cycle (Deming, 1950) the first step of implementation is to plan. Several steps had to be taken in order to actually apply the new end-to-end process. These can be found in the first chapter of the Implementation report (Appendix 8).

For each change that is made in order to get from As-Is to To-Be a table is made which provides all required actions to manage implementation of that change. Those tables provide the activity to be made, the participants, the result and the date on which the activity was performed. As can be seen, all of the scheduled activities that were needed to be done have been completed. However, when looking at the dates they seem to deviate and are not chronologically sequenced because of planning reasons.

6.3 Pilot results

What can be concluded after the implementation has been finalized? In other words:

What are the results of the quick wins implementation?

This sub-question is in fact answered by the Implementation Report (Appendix 8). This document has describes every step that has been taken during the pilot on the PM process of the ROM department. In this section the focus will be on the overall results that can be celebrated after the implementation phase.

LTLP tool
Perhaps the most valuable result of this project is the LTLP tool. This tool includes some major aspects of the PM process in its To-Be situation. These are:

1. Securing proper delivery of study results.
2. Insight in proceedings of new preventive plans.
3. Assurance by the Reliability Engineer by checking new preventive plans.

Preventive Planning
New preventive plans are now standardized, completed and maximally prepared. This has resulted in a significantly lower workload for the Corrective Planners and huge reduction of repeatability. Next to this the quality of preventive plans are now to proper standards. Another important win that has been made is the discussion of task lists with the craftsmen. This really appeared to be effective as lots of usable information and feedback was received.

Storage of documentation
The storage of documentation has faced a problem in the first phase of implementation. This problem was that the AIM Supervisors identified a risk that was perhaps bigger than thought in first instance. When storing documents in AIM it is considered as truth. However, as the time proceeds the outside situation might change which makes the operational documents incorrect. Therefore a meeting was aligned to discuss the risk with the responsible persons. An agreement was made to add a mandatory check on documents by the aOMC and to store the documents on the decentralized AIM database. The reason for this is that documents on the decentralized AIM database are not necessarily considered as true and correct.

Feedback loops
The feedback loops has resulted in a continuous improving cycle of the preventive plan quality. This is really valuable for Shell Pernis as high financial benefits can be made if this process continues to be. Another result has been earned by making a difference in feedback of practicalities and study contents. In this way the Reliability Engineers only received feedback relevant for them via the MTLP tool instead of practical issues which is not relevant for them. The MTLP tool therefore became even more effective.

Control points
Implementing the control points resulted in very important benefits. Firstly, no new plan was requested without the right information was received by the Preventive Planner. The check of the Reliability Engineer resulted in very valuable feedback and subsequently a change in the preventive plan.

POR meeting
The POR meeting was reintegrated in the agendas again. Because of the successful first meeting on the ROM and because of a POR meeting on RWH and RHP several more PUs followed this example by taking initiative to schedule a POR meeting. These PUs are RTA, RVC, COD and RDU.

Clean-up
A lot has been found that did not seem to be right in the existing preventive plans. The clean-up resulted in a major win of effectiveness of the preventive plans. More about this can be read in section 7.3.2.1.

Recommendations out of implementation
During the implementation situations has led to additional recommendations.

- *Engagement of the Preventive* Planners; The Preventive Planners should be equally divide their time.
  A. Decentralized: at the department to secure close contact and commitment with the PM preparation and execution. By doing so the Preventive Planner knows exactly what is going on in the following phases of the PM process. This will lead to quality improvement.
  B. Centralized: at the Central Office together with the other Preventive Planners to secure and improve a standardized work method.
- *Always arrange replacements*; During the implementation a Job Leader was outsourced to a project. Since no replacement was arranged a bottleneck was created in the process. Therefore, Shell Pernis should always arrange replacements for performing tasks of an employee outsourced to another PU or project.
- *Proactive mentality*; Participants of the PM process should always look ahead and adopt a proactive mindset. In this way waiting times and lead times will be decreased. If for example materials are not delivered on time so a PM activity cannot start, a Job Leader should see if any task on the schedule for the coming days can be done already.

7 Strategy

Strategic goals are highly significant for any kind of industrial business since it sets out a direction to pursue. According to A. Rastegari in his publication of *Strategic Maintenance Management in Lean Environment* (Rastegari, 2010) a good strategy can answer the following compressed question:

"How and when are we doing plan **A** to achieve **X**?"

In fact, by answering this question properly several really important things are required.
1. Goal (What to achieve)
2. Mission (When are we doing what to achieve the goal)

This might sound simple, yet this is not the case. To support this journey in finding the important answer A.C. Márquez has created a model in his *The Maintenance Management Framework* (Márquez, 2007) which can be found in (Appendix 3). In this model several aspects that add contribution in creating the right strategy can be seen:

A start should be made by setting the goal/objective for, in this case, PM at Shell Pernis.

7.1 Strategic goal/objective

Mostly significant in a business strategy is the strategic goal. In the question stated in the first paragraph of this chapter the 'X' to be achieved represents the goal. Setting the mission of the strategy ('plan A') requires a strategic goal. By sticking to the surveyed literatures an answer should be provided to the following sub-question:

What strategic goal for PM should Shell Pernis set?

As an introduction to this research report a problem definition was given. The problem was that the financial balance between PM and CM was not optimal. After further analysis on those numbers the current balance is:

$$\frac{\%\,Total\ Preventive\ Maintenance\ Costs\ 2015}{\%\,Total\ Corrective\ Maintenance\ Costs\ 2015} = \frac{68{,}32214436655198}{31{,}67785563344802} \approx \frac{68}{32}$$

These numbers are based upon the official cost reporting document over the year 2015 of Shell Pernis. The numbers (actual expenses for PM and CM of Shell Pernis in 2015) are unfortunately confidential and can therefore not be given.

"The ideal maintenance strategy is an 80/20 ratio of planned to reactive maintenance (…)" (O'Brien, 2013)**.**
In Appendix 6 the scorecard elements of the Maturity Matrix claims that 80% of PM is a best practice. (Smith, 2012)

Out of this citation and claim can be concluded that the desired balance between PM and CM should be:

$$\frac{\%\,Total\ Preventive\ Maintenance\ Costs}{\%\,Total\ Corrective\ Maintenance\ Costs} = \frac{80}{20}$$

Shell Pernis' Maintenance Excellence Supervisor has agreed upon this desirable balance. Therefore this balance will be the objective. For this very reason the strategic goal of Shell Pernis regarding PM should be:

Getting the ratio between PM and CM expenses at $\frac{80\%\,PM}{20\%\,CM}$.

7.2 KPI target

The KPI target of this recommended strategy is now to be set. In terms of properly designing the mission A.C. Márquez's Maintenance Strategy Model (Márquez, 2007) will be key. As can be sees in (Appendix 3) getting to the mission there are a few things to be done. To determine the KPI target the performance gap needs to be identified. This will be done by comparing the current status and the vision. The vision is the strategic goal and as concluded from performed analysis on the actual expenses of Shell Pernis on PM and CM in 2015, the current situation is a $\pm\frac{68\%\ PM}{32\%\ CM}$ ratio. The performance cap is now identified as a 12% deviation.
Our KPI target for this strategy therefore states:

Getting the ratio between PM and CM expenses from $\pm\frac{68\%\ PM}{32\%\ CM}$ to $\frac{80\%\ PM}{20\%\ CM}$ by closing the performance gap of ±12%.

7.3 Mission

Centrally posted by A.C. Márquez in his Maintenance Strategy model (Márquez, 2007) is the *mission*. Next to this A. Rastegari's strategy question (Rastegari, 2010) is again reviewed:

"How and when are we doing plan **A** to achieve **X**?"

As the 'X' (strategic goal/objective) to be achieved a prescription on how to get from the current situation to the vision is given. In other words, how could the performance gap be closed to achieve the strategic goal: the mission.

The mission will exist out of multiple things. Those could be a change, a clean-up, an improvement or an addition that will ultimately contribute to closing the 12% gap. Three different parts will shape the mission combined. The first is the new PM process which is explained in previous chapters. Secondly, existing preventive plans of Shell Pernis should go through a clean-up since the existing plans will not follow the first steps of the new process as they already followed these in the old process in the past.

7.3.1 Improved PM process: AS-IS process vs. TO-BE process

The first part of the mission is something already implemented in one of the PUs of Shell Pernis. This is the application of the new PM process (To-Be situation). In Appendix 10 a complete overview and step by step explanation of the entire To-Be situation is provides. Within this new PM process several aspects do actually contribute in achieving the strategic goal. These are:

Assurance of the Reliability Engineer

Everyone knows the whispering game where a bunch of people is sitting in a circle. The very first person whispers a random sentence to the second. The second repeats this sentence by whispering to the third. This continues until the last person has heard the sentence and has to say it loudly. 9 out of 10 times the sentence is completely changed.
Somewhat the same principle occurred PM process in the As-Is situation. For that reason three assurance points from the "first person" of this process being the Reliability Engineer are implemented. These assurances at the start, half way and afterwards avoids that preventive plans are not made as they were meant to be and not executed as they should be. The third, perhaps the most value adding assurance implementation in the new PM process, is the periodical evaluation. This evaluation, done on history of executed PM. Based upon the findings actions will follow that will add much in resetting the PM/CM ratio.

Numerical results can't be ascertained because this is a process which needs to be used and applied for some time. Only after a longer period of usage claims can be made on how much it contributes to the closure of the 12% performance gap.

Minimized repeatability
Secondly, the new PM process has reduced the repeatability in two ways. One; because of a completed task list when creating a new plan instead of completing it in the preparation phase, it will be done once instead of every work order interval. Currently a Corrective Planner spends 1.5 day (12 hours) per week on the preparation of preventive word orders. In the new situation he only spends maximally 0.5 day (4 hours) per week. A small switch to CM is made, since CM expenses need to reduce from 32% to 20%, an analysis is done on backlog of corrective work order preparation. The results are:

PU	Backlog
COD	38
CVP	39
RDU	103
RHP	49
ROM	53
RTA	88
RVC	33
RWH	86
TOTAL	489

Table 3. Corrective work order preparation backlog

By means of applying the new PM process a Corrective Planner saves one full day a week. The current four days on CM work order preparation is now expanded with 25%. Because the available time for corrective work order preparation grows this much the backlog will definitely decrease.

The second way of minimizing the repeatability which contributes to achieving the strategic goal is the storage of documentation in AIM. Instead of creating documentations for every single work order (both PM and CM work orders) storing them in AIM a time saving is realized. Currently, making documentations takes per order around two hours. When having it stored in AIM, it’s a matter of a brief check and printing which takes maximally 15 minutes. This means anytime a work order needs documentation(s) the work order preparation lead time got further reduced with:

$$Time\ saving/work\ order = \ 15\ minutes - 120\ minutes = \ -105\ minutes$$

Together with the reduced required time for the Corrective Planner these time savings become really significant. Shell Pernis weekly processes 1100 to 1200 work orders scattered over the 9 PUs. Even small changes therefore add a high amount of value to the processes.

Control points and feedback loops
The last change of the PM process that is applied in the To-Be situation is the control points and the feedback loops. Because of the control points, e.g. the overview and check of the Sr. Planner, prevention of mistakes is built in. Secondly, the feedback loops worthy contribute to continuous improvement of the preventive plan quality slinks in.

Again no numerical results can be ascertained because this is a process which needs to be used and applied for some time. Even after a longer period of usage it’s not really possible to observe concrete measurements on how much improved preventive plan quality adds to the mission of getting to an 80/20 ratio of PM/CM. What is concrete is the fact that a continuously improved plan which will (nearly) reach perfection does improve the PMs effect; And so, contributes to the mission of this strategy.

7.3.2 Clean-up existing Preventive Plans

A major contribution in reaching the strategic goal is a clean-up of the existing preventive plans. This is done in two ways; Quantitative and Qualitative. The first way is to determine what existing plans are indeed preventive plans that add value to the PM performances and what preventive plans can be deleted or merged.

The second way is to clean-up in terms of improving on quality. Quality improvement for preventive plans means standardized task lists and standardized titles (symbols, origin and standardized description). The two ways of cleaning up the preventive plans both contribute to the process' performance improvement in different ways. For the quantitative clean-up it means useless plans won't end up in the schedule anymore which is a big advantage. This will both directly and indirectly save costs expenses for a maintenance department of Shell Pernis. It therefore contributes to the mission of achieving the strategic goal. The qualitative clean-up indirectly contributes to the strategic goal since it improves the efficiency of the PM process. The argument for this is that plans will be understood better, overviews available, analyses are possible to do, further improvements can be planned and implemented.

7.3.2.1 Quantitative Clean-up

In the Report of Improvements (Appendix 7) one of the suggested improvements is to clean-up existing plans on quantity. During the implementation phase the Preventive Planners of Shell Pernis have performed the clean-up. Currently all preventive plans that will be analyzed for this clean-up are done. An overview of all preventive plans is shown below.

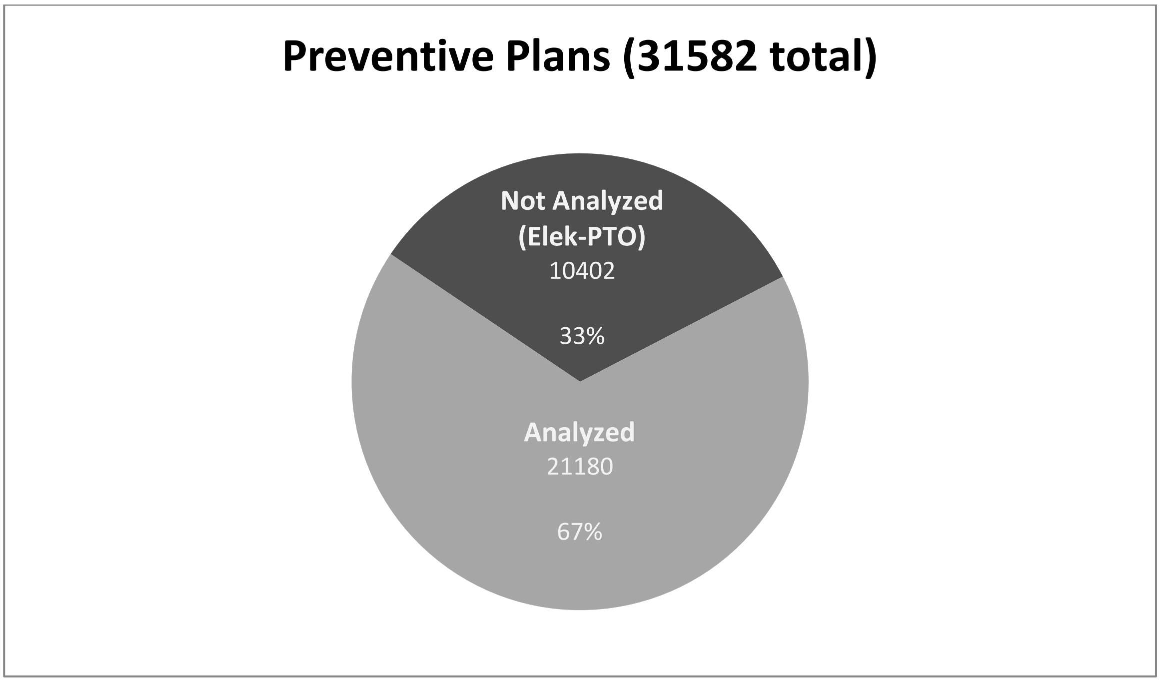

Figure 12. Preventive Plans for clean-up

The Elek-PTO plans (10402) are not analyzed in this quantitative clean-up. The reason for this is that these plans are possessed by another group at Shell Pernis. The Preventive Planners have no further control on these plans. The remaining preventive plans (21180) are analyzed. During the analysis the preventive plans were set against several criteria. Those criteria ultimately have determined whether a preventive plan should stay in existence or should be deleted. The results are:

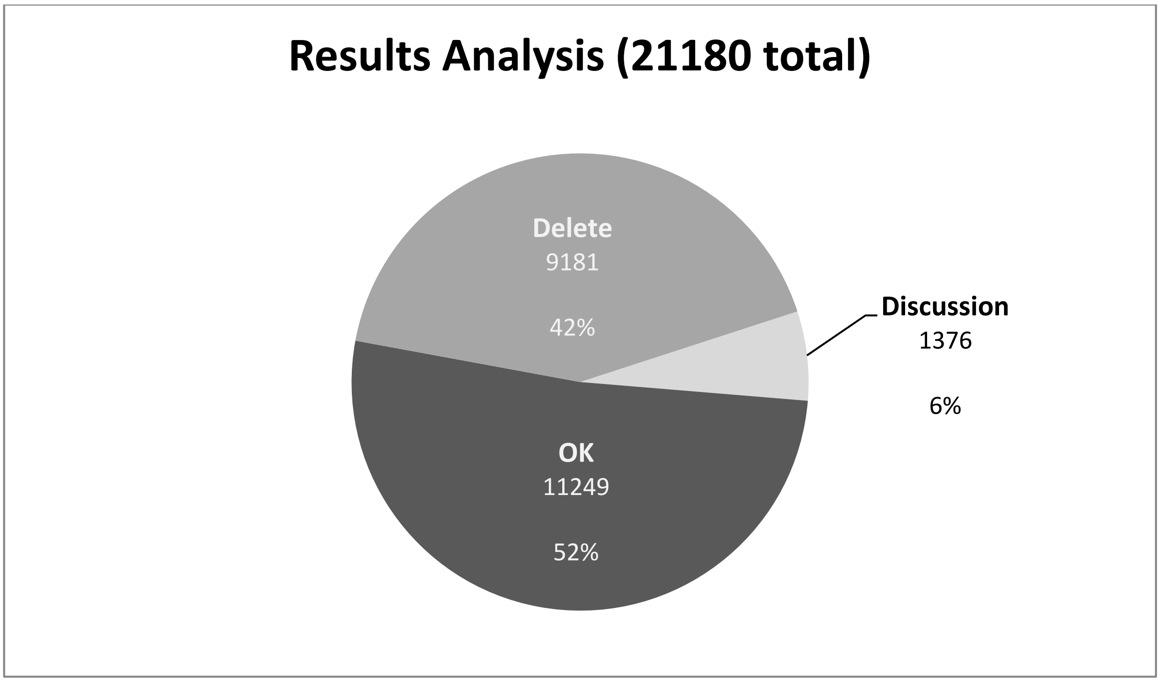

Figure 13. Results Analysis

From the 1367 plans approximately 750 plans are expected to be deleted. This means that after the first phase of the quantitative clean-up existing plans that remain are:

$$Remaining\ Preventive\ Plans = \ 10402 + \big(11999 - (1376 - 750)\big) = 21775$$

This means the existing plans are cleaned up quantitatively with:

$$\%\ Preventive\ Plans = \frac{(21775 - 31582)}{31582} \times 100\% \approx \ -31{,}05\%$$

The amounts of preventive plans are actually reduced. Nevertheless the amount of PM is not reduced since the preventive plans deleted were inactive or appeared useless and were therefore not executed and were not adding value to the failure prevention of assets. For that very reason the economical expenses on PM will not drop directly, but does optimize the PM system of Shell Pernis. Indirectly this clean-up will therefore contribute to the mission.

7.3.2.2 Qualitative Clean-up

Only after having performed the quantitative clean-up a qualitative clean-up makes any sense. The qualitative plan includes the following contents:

Right symbol in title (@, #, $ or -)

The title of a preventive plan starts with the right symbol. What symbol needs to be chosen for what preventive plan is explained as:

@ Contractor services and/or materials ordering required.
# No contractor services and no materials ordering required.
- Sometimes contractor services and materials ordering required, sometimes not.
$ SBKD services.

Derived from a RCM, IPF, HEMP or EI study
It is clear what type of study is fundamental for every specific preventive plan. By means of adding the study name abbreviation next to the symbol in the title, all people involved are properly involved about the preventive plan fundamentals and type.
Standardized task list
The preventive plans contain a standardized task list. This task list is selected on type of equipment. This means for every type of equipment a standardized task list has to be made concerning PM. A standardized task lists contains the right tasks in the right sequence, correct (main) work center(s), efficient amount of work and duration hours and correctly linked graphics.

Discussed task list and checked preventive plan
The task list of this preventive plan is discussed with a craftsman of the main work center of the work order that will be generated by the plan. Possible adjustments are considered and applied where needed. After this is done, the Reliability Engineer that has performed the study checks the task list and rest of the plan. The LTLP flow in the Living Program tool will be supportive in this.

To wrap up; Shell Pernis' target in terms of preventive plan quality is that a preventive plan owns all above mentioned elements.

7.3.3 Innovation

An innovative mature PM environment is the last part of this strategic mission. R. Smith's PM Program Maturity Matrix (Smith, 2012)(Appendix 6) is central in trying to find future innovations while also other sources are attended in search of useful innovations for Shell in order to achieve the 80/20 ratio of PM/CM.

Operations involvement
Something what a big business like Shell Pernis often loses is the flexibility. It appeared that organizations like Operations and Maintenance grew apart and became independent businesses rather than a well cooperating lubricated machine. An environment where Maintenance knows exactly what Operations is doing and vice versa. Since this is not the case PM could dramatically lose its effect as it is unknown how all equipment is actually operated.
For example; A pump is preventively maintained every 6 months because the design specs are: max temperature = 150°C, max pressure = 3.0 Bar.
Let's assume Operations decide to use this particular pump above its design specs at a 200°C temperature and 3.5 Bar for whatever reason they might have. This means your PM policy for this pump to maintain it every 6 months is likely to lack on effect as the failure will most probably occur earlier.

We did some further questioning to experts on how much Shell Pernis actually does operate above design specs. One plant was taken as sample and the following numbers were identified:
According to the sum of design specs the plant would be able to:

Sum of Design spec:	Capacity = 4000 tons a day.
Actual data:	Capacity = 6000 tons a day.

The actual manufacturing amount is 6000 tons a day. This means for this plant PM is scheduled such assuming the 4000 tons a day (=100%) while the plant is actually operating at **150%** of its initial capacity. Conclusion: PM is likely to lose its effect which results in unplanned downtime and a huge amount of CM.

In the near future Shell Pernis should spend effort to solve this problem which will highly contribute to the reset the PM/CM ratio to an 80/20 ratio. What could be a future innovation that would significantly add value to the strategic mission is the following principle.

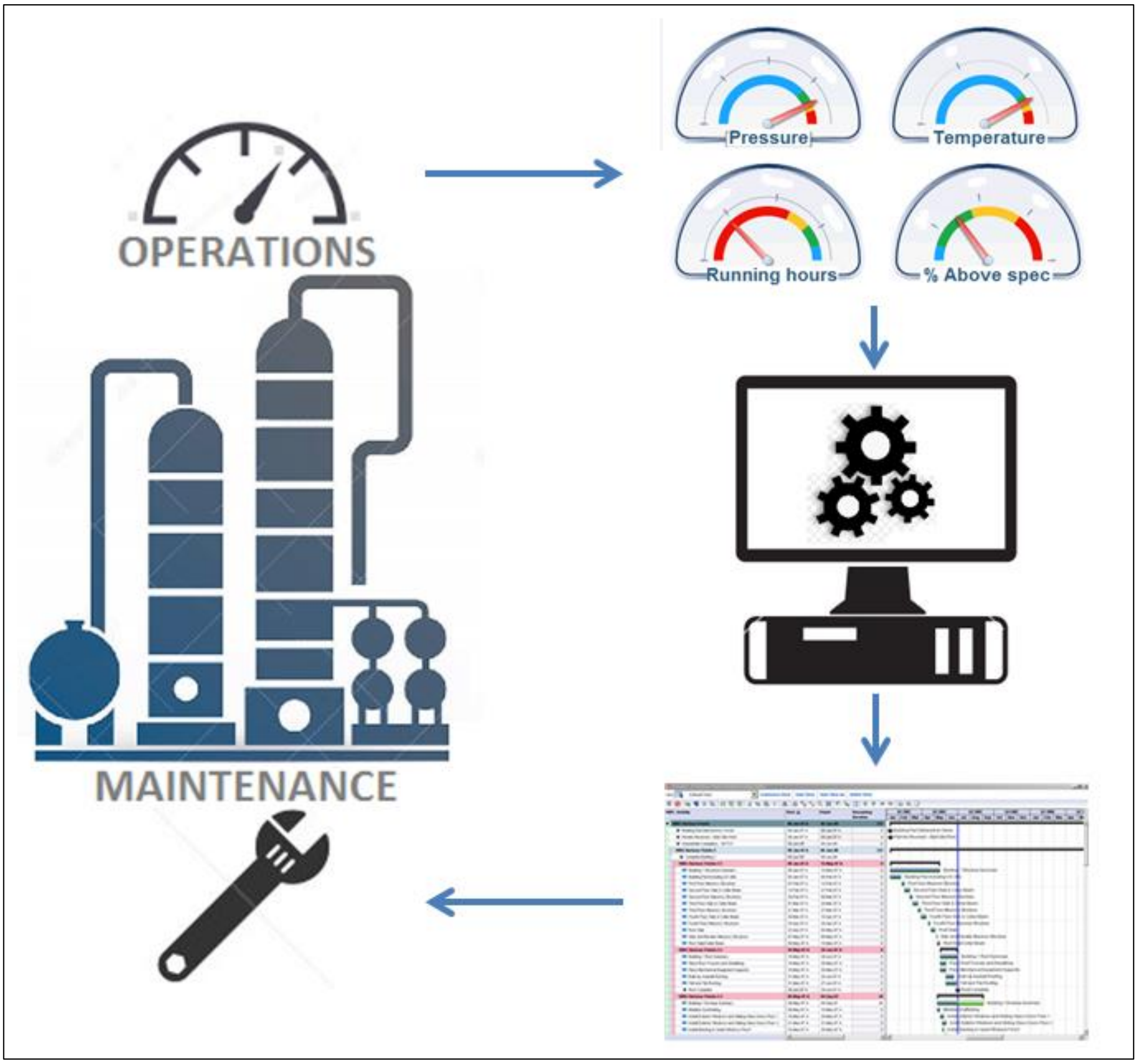

Figure 14. Future Preventive Maintenance principle

The idea behind this is simple. Instead of basing PM on studies and design specs PM should rather be based upon realistic usage specs.

1. Operations operate a plant to a certain capacity.
2. Operating data is monitored narrowly.
3. Programmed software calculates whether PM is required for every part of the plant based on:
    - Usage conditions (Pressure, Temperature, Environmental conditions etc.).
    - Usage hours (#Hours operated).
    - Last performed PM on equipment.
4. Weekly schedule is automatically made and work orders can be generated and prepared.
5. PM is executed according to schedule.

This means the following: Because of decisions made to manufacture above design spec, it means a choice is made to earn more money with manufacturing despite higher maintenance costs. This is a choice probably not made by the maintenance department. Nevertheless this will sorely confuse the PM/CM ratio since CM costs will incredibly increase. However, to restore this ratio the PM schedule has to be based upon the usage specs. By means of this PM will not lose its effect and CM costs will drop.

Though, PM costs will increase as the intervals of PM activities will become smaller; However, CM costs should drop if PM interval becomes smaller. Therefore, regardless of single values, Shell Pernis should identify the optimal increase in operating throughput using the following formula:

$$Benefit = \Delta Manufacturing\ Revenue - \Delta PM\ costs - \Delta CM\ costs$$

If the above mentioned formula equates a positive number, the suggested increase in throughput should be accepted. If the formula equates a negative number, the suggested increase in throughput should be declined. Referring back to the strategic goal; if the principle previously explained in Figure 14 is used the financial PM/CM ratio will incline a big shift from the current 68/32 ratio to the desired 80/20. Next to that, the most optimal operational revenue will be made.

Mentality
What is really the mentality or mindset of the mechanics, craftsmen and Job Leader or any other participant of the PM process? Is this really to pursue the failure prevention? In other words; Is the prevention of failure truly the no. 1 goal? (Smith, 2012). Or is it rather more or less performing what's on the schedule as quick as possible to be able to leave early every day? To be clear, this does not suggest above speculation is actually true. Only, is it assessed by any mean to make sure the right mentality of PM is present is Shell Pernis' department organizations, especially in the executive layer of the organization? The *Expectations* element of the Maturity Matrix (Appendix 6) states "Prevention of failure as the no. 1 goal" (Smith, 2012) as the best practice in terms of mentality. It should therefore be a strategic milestone to examine this mentality in the PM organization of Shell Pernis.

7.3.4 Required resources

Strategic goals often can't be achieved without any additional resources. For this very reason this paragraph focusses on answering the sub-question:

What resources are required to achieve the strategic goals?

We have set up the mission in three main parts; the new end-to-end PM process, the clean-up of all existing PM plans and innovative theory. For these three parts several additional resources are required. These will be briefly explained.

Sr. Preventive Planner
The first thing which is definitely required is a Sr. Preventive Planner. This person should take control on the newly implemented PM process in the To-Be situation on the ROM department. Next to this, this person should expand the implementation to all other PUs of Shell Pernis. Another required resource might be an extra Preventive Planner since one Preventive Planner has left and only three remain for the entire site. This directly leads to the next required resource.

Man hours
After some discussions with several people within Shell Pernis' organization about this subject one thing became crystal clear; Time and effort is highly required. Business adjustments never depart properly if no sufficient time and effort is invested on it. It is called 'investment' because multiple people will need multiple hours for this which will indirectly cost money.

Software development
The innovative way of determining the PM activities for Shell Pernis as explained in section 7.3.3 requires two types of software. Firstly, software for the maintenance department that monitors operating data narrowly. Secondly, software that provides the right PM activities for specific equipment based on the data it receives from operations via the previously explained software.
A research should be performed on identifying the required capabilities and criteria for these two types of software.

Integration project
To complete the introduced innovation a project of acquiring and installing the software is required. The project should have a total scope which means it starts with determination of the software, development of the software, integrating the software, implementing and testing the software.

7.4 Strategy summary

As major part of this project this strategy is a long term view on what Shell Pernis should achieve with PM in the future. This achievement is set by the current financial PM/CM ratio which is approximately 68%/32%. According to John O'Brien's theory (O'Brien, 2013) and R. Smith's Maturity Matrix (Smith, 2012) this should be a 80%/20% which results in a 12% performance gap that needs to be closed also called the KPI Target (Márquez, 2007).

Achieving this KPI Target demands a mission. The mission is divided into three parts.
To start off the mission entails the application of the new PM process as introduced and explained in the fourth chapter of this report. Next to this a clean-up of existing preventive plans is highly required and will significantly improve the quality of PM of Shell Pernis and is therefore the most important mission section. The clean-up exists of a quantitative and qualitative clean-up where performing the quantitative clean-up first sues the qualitative clean-up to be more effective.
Last but not least contribution of the mission of achieving the KPI Target is the innovative PM treatment. By usage of two smart software Shell Pernis will be able perform PM only when it is actually required instead of predetermined PM tasks which do not take into account any up-to-date conditional circumstances. This innovation will probably only survive if the right mentality is present all over the organization, from top to bottom. A proactive, failure preventive mindset instead of simply just execute what's on the schedule. This requires an organization where every participant thinks along and cooperates dedicatedly.
The required sources for achieving the strategic goal are primary an investment in time and effort. Shell Pernis should realize what a cleaned up, continuously improving PM process can deliver both financially and on HSE perspectives. For the innovational PM policy explained in section 7.3.3 two types of software are required which probably has to be developed and engineered with high involvement of Shell employees. For the actual implementation of this policy a big project needs to be started since this is not something that is changed from one day to another.

In terms of time planning no proper estimates can be made for several reasons. The prominent reason is that it depends on how much effort and time will be spent and by whom. What can be said is that the improvement curve is likely to flatten in time. This is because the biggest fish will be caught as first which results in a steep performance improvement in the first phase of the mission.

8 Conclusion

The PM process that is in place in Shell Pernis is not well structured, organized and standardized. Furthermore, no clear strategy is set up to close the performance gap between the current and the desired PM/CM financial ratio of 80/20. These problems have led to the research question. This chapter answers the research question and the major deliverables that solve the problem are explained. After that this conclusion recommends Shell Pernis how to follow up this project.

8.1 Products

After the execution of the project several products are made. By referring to the research question:

What end-to-end process does Shell Pernis need towards an improved Preventive Maintenance strategy?

this project has two major deliverables to be conveyed to the client. These are the new end-to-end PM process and a PM strategy. The deliverables have been addressed in the project scope and will therefore count as the answer to the main research question.

8.1.1 Process

The end-to-end PM process that Shell Pernis needs to apply has four improved aspects in comparison to the As-Is situation.

1: The delivery of the reliability study results is now done in the LTLP tool by the Reliability Engineer. Mandatory fields in this tool assure that the right information is provided to the Preventive Planner. Because of a required check by Reliability Engineer before a request can be closed the correct translation from study to preventive plan is assured. Next to these advantages, a clear overview of all new plans and plan changes is accessible for anyone.

2: The preventive planning process has changed. Fully completed newly made preventive plans are the standard. A proper plan has the right symbol and study name in the title of the items, task lists are standardized and completed with information like scaffolding and isolation dimensions, crane types, material codes/dimensions and document numbers. Every new preventive plan is discussed with a craftsman to avoid or solve operational and doability issues. A complete preventive plan reduces preparation workload and will be more effective in the execution phase.

3: The control points are embedded in the process. The first one is the check by Reliability Engineer as explained in the first paragraph. The second one is the Sr. Planner's check as the PM work orders appear on the planning list. The aOMC subsequently checks the work order on content from an operational point of view. In the end of the process, after execution, the history will be analyzed as the Reliability Engineer puts in another piece of assurance. This will be done by sample and annually based on the Bad Actor Process.

4: The loop between ME and the Living Program is now closed. Feedback flows are added and exist of three major loops.
A. Feedback of changes in a work order directly to the Preventive Planner. Feedback can be initiated by the Reliability Engineer, Sr. Planner, Corrective Planner, aOMC or Scheduler.
B. Feedback regarding scaffolding, isolation etc. to be delivered verbally or by mail.
C. Feedback regarding study contents, to be delivered via the MTLP tool.

8.1.2 Strategy

A PM strategy has been set for Shell Pernis because no clear vision and strategic goal was available. The goal is to go from a financial 68/32 ratio of PM/CM to 80/20 ratio. Comparing the current situation with the desired situation shows a 12% performance gap.

The strategic goal therefore states:
Getting the ratio between PM and CM expenses from ± $\frac{68\%\ PM}{32\%\ CM}$ to $\frac{80\%\ PM}{20\%\ CM}$ by closing the performance gap of ±12%.

According to Márquez' strategy model (Márquez, 2007) a mission is required to close the gap. The mission is divided into three parts:
1. Perform a quantitative and qualitative clean-up on existing plans.
2. Apply the new end-to-end process on all PUs by using Deming's PDCA principle. (Deming, 1950)
3. Implement an innovational policy where:
    A. Operational utilization of equipment forms the basis of the PM schedule.
    B. Proactive mindset regarding maintenance at Shell Pernis by internal assessment.

These three aspects form the path forward to the goal which is of considerable interest for Shell Pernis. This financial 80/20 ratio for PM/CM is the vision. In fact this opportunity can significantly contribute to Shell Pernis' top quartile maintenance performance ambition.

8.2 Development

PM at Shell Pernis is something that should be developed endlessly. Recommending multiple actions, constraints to be solved and advised further researches is provided which are hereby counseled.

8.2.1 Recommendations

The main recommendations for Shell Pernis' PM organization are listed and briefly amplified.

- *Expand implementation;* Shell Pernis should implement the new end-to-end PM process on all PUs. Standardization of the improved PM process all over Shell Pernis is required. Application o a standardized process allows Shell Pernis to improve PM on the refinery. The detailed work instruction can be found in Appendix 10.
- *Further strategy development;* Shell Pernis should further develop the strategy to make it perfectly fit in the organization. This should be done until the 80/20 financial ratio of PM/CM is reached.
- *Qualitative clean-up of existing preventive plans*; Shell Pernis should standardize all task lists of the PM plans. Next to that the task lists need to be filled with all available information to make the task list complete. The title of a PM plan should contain the right symbol and the study name. This clean-up should be done after the quantitative clean-up is entirely finished.
- *Cluster PM plans as prominent activity*; Shell Pernis should challenge financial optimality again and again for PM plans instead of blindly execute according to schedule. Clustering the PM plans properly will result in lower asset downtime and lower service costs to contractors.
- *Standardized task list for PM plans in GSAP*; Shell Pernis should create a library of tasks list where operations, maintenance and contractors have agreed upon. This significantly contributes to maximize PM quality because of standardized operations and procedures.
- *Employ Sr. Preventive Planner*; Shell Pernis should employ a Sr. Preventive Planner. This person should take control of the new PM process and expand it to all PUs. Next to this the Sr. Preventive Planner should guide the clean-up processes and guard standardization.
- *Employ new Preventive Planner*; Shell Pernis should employ an extra Preventive Planner because of a move of one of the four Preventive Planners. Currently only three Preventive Planners remain which is too few for the entire refinery.

8.2.2 Constraints

In fact, the PM process contains one major constraint which is the ERP system GSAP. GSAP does not allow variable PM intervals and does not allow editing of BFD after work order is approved. This really constrains the deferral procedure. What should be done is contacting the GSAP firm when Shell Pernis has written a proper business case on what should be changed in the system.

8.2.3 Follow-up recommendations and research

Recommended researched that could follow up this research will surely add value to Shell Pernis. The following "follow-up" researches are:

1. *Continuous improve process;* The PDCA cycle should be continued to be followed for process implementation on the ROM department and expanding to the other PUs of Shell Pernis. Because this is a never ending process it needs to continue after finalizing this project.

2. *PM plan clustering*; A study on how to cluster PM plans optimally. This principle is explained by a simple example: If two tanks need to be preventively maintained by a contractor, this can be done in one plan so it will generated one work order and the contractor only have to come once. Next to this, permits are only to be requested once. This will lead to financial benefits. A plan needs to be made in order to determine the right approach to achieve these benefits.

3. *Implement innovational PM policy;* A project on how to implement the suggested innovational PM policy as explained in the strategy. As explained in section 8.2.1 the suggested innovation in the strategy needs to be figured out in more detail. Obviously this requires a proper study and research.

4. *Assessment of Reliability Engineer capabilities*; Out of scope for this project, but the quality of the Reliability Engineers does not always seems to have Shell quality standards. During the project it happened several times that preventive plans generated a work order containing PM tasks on equipment that didn't even exist. This resulted in doubts towards the Reliability Engineers' quality. Shell Pernis should therefore assess if any training or changes for the Reliability Engineers are required.

5. *Maintenance Engineers*; Shell Pernis should pay effort in a study if Maintenance Engineers are required. Also out of scope or this project, but during the project it did not become clear who had the overall control and overview on Reliability Engineering, PM performances and CM performances. It seemed like every group is performing their own piece of work without having someone for every PU that assesses what maintenance should be done on what equipment. Shell Pernis should therefore perform a research on if these Maintenance Engineers are required and beneficial.

6. *Tool and database for deferral process*; For the same reasons the Living Program tool and database was developed this should be done for the deferral procedure as well. This was not done during this project because of time scope.

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